Revised.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 52.

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THE SUGAR BEET:

CULTURE, SEED DEVELOPMENT, MANUFACTURE, AND STATISTICS.

BY

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U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF CHEMISTRY,
Washington, D. C., February 7, 1899.

SIR: I have the honor to transmit herewith the manuscript of the revised edition of Farmers' Bulletin No. 52.

The subject-matter of this bulletin remains practically the same as in the original edition. It was found necessary to revise the statistical part, however, and to bring it up to date.

It is hoped that in its new form this bulletin may prove as beneficial as its predecessors in directing the interest which is being manifested in the culture of the sugar beet and in the manufacture of sugar therefrom into reliable channels of experiment and investigation. This edition makes the total number of copies of this bulletin which have been issued 200,000, and the demand for it seems to be undiminished.

Respectfully,

H. W. WILEY, *Chemist.*

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE SUGAR BEET.

INTRODUCTION.

Among the farmers of the country there is in general an erroneous opinion respecting the manufacture of beet sugar, especially concerning the cost of a factory. It is well that our farmers should cherish no illusions in regard to this matter. The manufacture of beet sugar is an industry entirely distinct from agriculture, and can only be successfully accomplished by the investment of large capital under the direction of skilled artisans. From the nature of the process, it is quite improbable that any simple method of home manufacture of beet sugar will ever prove commercially successful. The juices of the beet are extracted with difficulty. They contain large quantities of mineral salts which render the crude sugar and molasses made therefrom bitter and unpalatable. Simple processes for the extraction of the juice can at best remove only from 60 to 70 per cent of the sugar which the beet contains, and thus a percentage of loss is incurred which at the very outset renders it impossible for a home apparatus to compete with a large factory. Beet sugar, for the reasons given above, can not be used in the raw state, as is the case with the products derived from the sugar cane, sorghum, and the maple tree. The refining of the sugar is a process which requires an expensive outlay for machinery and a high degree of supervisory skill. It can not therefore be accomplished upon the farm. The various schemes which have been proposed whereby the farmer is assured of the possibility of preparing a crude product to be subsequently shipped to a central refinery are not practicable on account of the radical difficulties above outlined. The low prices at which sugar is sold render imperative in the process of manufacture the most economical methods, which are only made possible by the use of improved machinery operated under the direction of technical experts. The farmers of this country, as is the case with those of Europe, in respect of the beet sugar industry, must be satisfied with acquiring the requisite degree of agricultural skill to produce a crop of beets with a paying tonnage and a high content of sugar.

One of the remarkable facts shown by the statistical tables in this bulletin is found in the information they contain showing that the sugar beet has been able on demand to supply the remarkable deficiency in the world's sugar crop produced by the Cuban war. In three years the supply of sugar furnished by that island has fallen from 1,000,000 to

about 100,000 tons, and yet there has been no appreciable deficit noticed in the total sugar production of the world.

The remarkable opportunities for the extension of profitable agricultural industries in this country, through the medium of the sugar beet, should not be suffered to pass unimproved, and the farmers of our country should not rest satisfied until they see our own fields produce the sugar which we consume.

CLIMATIC CONDITIONS AFFECTING THE GROWTH OF THE SUGAR BEET.

Experience has shown that the sugar beet reaches its highest development in north temperate latitudes. So far as the production of beets with high tonnage is concerned, it is found that this can be accomplished far to the south, but beets grown in such localities are, upon the whole, less rich in sugar and less suitable for the manufacture of sugar than those grown farther north. It must be remembered, however, that the expressions north and south do not refer to any absolute parallels of latitude, but rather to isothermal lines, which in many cases run obliquely to the parallels of latitude and in some cases cross them almost at right angles. As a result of many years of careful experimentation, it may be said that as far as temperature alone is concerned the sugar beet attains its greatest perfection in a zone of varying width through the center of which passes the isothermal line of 70° F. for the months of June, July, and August. This zone for this country is shown in the accompanying map (fig. 1).

THE THEORETICAL BEET-SUGAR BELT OF THE UNITED STATES.

This isothermal line, for the United States, begins near the city of New York and passes up the Hudson River to Albany; thence turning westward, it runs near Syracuse and passes in a southwesterly direction, touching the shore of Lake Erie near Sandusky, Ohio; turning then in a northwesterly direction, it enters Michigan and reaches its highest point in that State near Lansing; then going in a southwesterly direction, it enters the State of Indiana near South Bend, passes through Michigan City, then in a northwesterly course continues through the cities of Chicago and Madison, reaching its highest point near St. Paul, Minn. Thence it extends in a southwesterly direction until it enters the State of South Dakota, where it turns again northwest and reaches its highest point in Dakota just above the forty-fifth parallel of latitude, where it crosses the Missouri River. The isothermal line then turns almost due south, following very closely the one hundred and first degree of longitude until it leaves the State of Nebraska near the northeast corner of Colorado; passing in a southwesterly direction through Colorado, it reaches, at Pueblo, almost to the one hundred and fifth degree of west longitude, whence it passes in a slightly southeasterly direction into New Mexico, turns to the west, and crosses the one

hundred and fifth degree of longitude at about the thirty-second degree of latitude. Then turning westward, it passes in a very irregular line through the States of California, Oregon, and Washington.

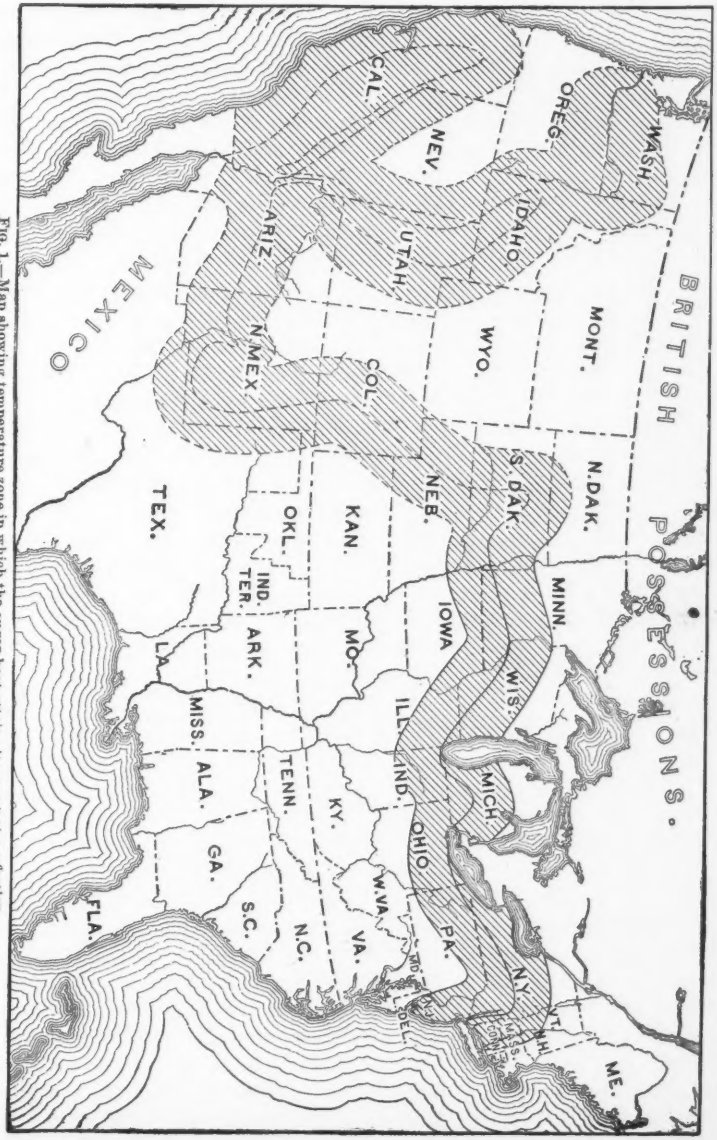

Fig. 1.—Map showing temperature zone in which the sugar beet attains its greatest perfection.

Extending a distance of 100 miles on each side of this isothermal line is a belt which, for the present, may be regarded as the theoretical beet-sugar area of the United States. There are doubtless many localities lying outside of this belt, both north and south, in which the sugar beet will be found to thrive; but this will be due to some exceptional qualities of the climate or soil and not to any favorable influence of a higher or lower temperature. A mean temperature of 70° F. in the summer, however, must not be regarded as the only element of temperature which is to be taken into consideration. In those localities where the winters come early and are of unusual severity will be found greater difficulties in the production of sugar from the sugar beet than in those localities where the winters are light and mild, although the mean summer temperature of both localities may be represented by 70° F. As an illustration of this difficulty may be cited northern Nebraska and South Dakota, where the winters are of great severity, and southern California, where there is scarcely any winter at all.

The mean summer temperature of these localities is about the same, but the continuation of a semisummer temperature through the winter in southern California greatly favors the growth and manufacture of the beets. In northern Nebraska and South Dakota the beets, which are to be manufactured during the winter time, have to be protected by expensive silos. In southern California and other places similarly situated the beets can be protected without any covering, or at most with only a slight covering of leaves or straw. The season for planting in a mild climate is also longer. For instance, in southern California planting can commence as early as January and continue till June, thus giving a beet crop coming continuously into maturity from the 1st of August to the 1st of December. In other localities the planting must be accomplished in a short time, say from the 10th of May till the 1st of June. Before the first of these dates the ground will be too cold for planting and after the second the season will be so late as to prevent the maturity of the beets before frost. When the field is properly plowed and subsoiled in the late autumn the farmer will be able to take advantage of the first favorable opportunity in the spring to prepare the surface of the soil and plant the seed.

CONDITIONS OF PRECIPITATION.

Although conditions of temperature must be taken into consideration in selecting sites for beet-sugar factories, yet in addition to the thermal conditions must also be studied those of rainfall. The sugar beet requires a certain amount of moisture in order to produce its normal crop. This moisture must be derived either from precipitation in the usual way, by irrigation, or else the soil must be of that particular quality which will allow subterranean moisture to reach the rootlets of the plants. Soil of this latter kind appears to exist in many localities in California, where beets are grown almost without rain. The porous

and sandy soils adjacent to many of the Western rivers, such as the Platte River in Nebraska and the Arkansas River in Kansas, also appear to furnish a sufficient amount of subterranean moisture to produce a good crop in connection with the rainfall, of which, however, but little is expected in those localities during the summer months. Where there is little subterranean moisture, and where irrigation is not practicable, the endeavor should be made to secure localities for the growth of the sugar beet where an average summer precipitation of from 2 to 4 inches per month may be expected. There are many conditions of agriculture, however, under which the beet becomes quite independent of extremes of precipitation. The beet may thrive with very little rainfall or with a great deal, if properly cultivated in a suitable soil.

GROWTH OF BEETS ON IRRIGATED LANDS.

The experience of more than ten years in California has shown that the climatic data, regarded as of prime importance in beet culture in Europe, can not be regarded as rigidly applicable to this country. The successful growth of sugar beets in the arid regions of our country, with and without irrigation, has introduced a new factor into the science of beet meteorology. While the arid area on which beets can be grown without irrigation is probably confined almost exclusively to the coast valleys of California, the successful commercial production of sugar beets in Utah and New Mexico has opened up a new and extensive field for the extension of the sugar industry over large areas suited to irrigation in the western and southwestern regions of the United States. It is certain now that Colorado, Utah, New Mexico, Idaho, and Arizona may become great sugar-producing States, not excluding other areas in the arid region. California has already set the pace of progress, and the other arid States will not be slow to follow. The high cost of good irrigation renders it imperative that the areas under culture be devoted to a crop which is capable of producing a more valuable yield than is afforded by cereal culture. Of all the home markets for our domestic agricultural products, there is none so insistent nor so expansive as that for sugar. With an annual consumption of 2,000,000 tons, and with a certainty of rapid increase, the demand for sugar promises to be the salvation of American agriculture.

The northern parts of our Eastern and Middle States and the States of Oregon and Washington have at least an equal chance for the successful production of beet sugar with the fields of Germany and France. The irrigable parts of the great Southwest, it is believed, have advantages of soil and climate which will enable them to enter into competition even with the Hawaiian Islands and Cuba. To be able to control the moisture in the soil is a matter of prime importance to the beet grower. In the arid region the beet can be left to mature at the proper time by withholding the water. Subsequently there is no danger of loss due to second growth, so easily induced by late warm autumnal

rains. In a dry soil the beet can endure without damage a low temperature, which would prove quite disastrous in a wet climate. More complete maturity may be thus obtained, and a more leisurely harvest. In fact, there is no staple crop which can compete with the sugar beet in demanding the favorable attention of those interested in irrigation. If a net profit of from $10 to $20 per acre can be secured, from $100 to $200 per acre can be paid for the land. It is estimated that nearly 100,000,000 acres of land in the arid regions of the United States may eventually be irrigated, being nearly one-fifth of the total area. Of this area perhaps 10 per cent are capable of easy and speedy irrigation. One million acres planted to beets would yield, under intensive culture, a quantity of sugar sufficient, with the Louisiana product, for domestic consumption. There is nowhere in sight a more promising prospect for agricultural development than in the production of sugar beets on irrigated lands.

FIG. 2.—White Improved Vilmorin Sugar Beet.

VARIETIES OF BEETS.

All kinds of sugar beets are botanically identical with the common garden beet, *Beta vulgaris*. The differences in varieties have arisen by reason of special selection and culture, producing a pure strain of some valuable peculiarity in the beet. These accidental valuable qualities, by careful selection, have become fixed, and are associated with certain external properties which have thus come to be regarded as distinguishing characteristics.

The shape and size of the beet, its color, the character of the foliage, whether erect or spreading, etc., are the most frequent marks of distinction. The beets are also frequently designated by the names of those who have developed them, by the name of the town or locality in which they have been grown, or by their color.

Among the more frequently occurring varieties grown in Europe may be mentioned the Vilmorin Improved, Kleinwanzlebener, Improved Kleinwanzlebener, White Excelsior, White Imperial, Simon Le Grande, Florimond and Bulteau Desprez Richest, Brabant Sugar Beet, Rose Imperial, Demesmay, etc.

The two varieties which have been most widely grown in this country

are the Vilmorin Improved and the Kleinwanzlebener. The certainty that the seed has been grown according to the most scientific methods is of greater importance to the beet grower than the variety. The beet has reached such a high state of perfection as to make the least degree of laxity in its treatment exceedingly dangerous to its qualities.

The general type of the Vilmorin Improved is illustrated by fig. 2. This beet is the result of thirty-five years of methodic and persevering selection based upon the lines to be indicated hereafter. In regard to its preservation, it is recognized that it holds its sugar content better than any other variety. In those factories in which the Improved Vilmorin is manufactured in connection with other varieties, it is the custom to reserve this variety for the end of the season and to work up the less reliable beets at an earlier date. It is also said to resist better than any other variety the unfavorable influence of certain characters of soil and of certain manures. In black soils, rich in organic matter, it gives great industrial results, while most other varieties of beets become watery or saline in excess.

FIG. 3.—Kleinwanzlebener Sugar Beet.

Excessive quantities of nitrogenous fertilizers, which are carefully excluded from ordinary varieties, can be applied with safety to the Improved Vilmorin, as a great number of experiments has shown that this can be done without serious deterioration in the quality of the sugar and with a considerable increase in weight. From thousands of analyses it has been established that the percentage of sugar which can be obtained with this variety is about 16. Its average yield under favorable conditions can be stated to be from 12 to 16 tons per acre.

Perhaps more important for general cultivation than the Vilmorin variety is the beet known as the Kleinwanzlebener, which at the present time has probably a wider cultivation than any other sugar beet. The general character of this beet is shown by fig. 3.

This beet has a conical root, straight and even, quite large at the head and rapidly tapering. It is distinguished from the Improved Vilmorin by its brighter color and its lighter colored leaves, which are beautifully undulating or scalloped about the edges. Coming from a cross in which the Improved Vilmorin entered largely, the Kleinwanzlebener is to-day a fixed variety and is equally well produced in France and Germany. It succeeds in soil of an alluvial nature and average richness and on level plateaus. In soils very rich in humus it ripens poorly and loses much of its richness. Like the Vilmorin Improved, toward the end of vegetation its leaves are completely spread. In those conditions of culture where the Improved Vilmorin gives from 12 to 16 tons per acre, the Kleinwanzlebener gives from 14 to 18 tons. It is, however, generally inferior to the Vilmorin Improved in saccharin richness, which the whiter and more watery appearance of its flesh would make known at first view. Nevertheless, from 13 to 15 per cent of sugar can be obtained in the beet in field culture.

FIG. 4.—Brabant Sugar Beet.

The Brabant sugar beet is altogether different in aspect from the preceding varieties. It is long, rising well above the level of the soil, and carries a foliage vigorous in growth and upright in position. This variety would seem at first view to have come from the white varieties

used for forage; nevertheless, its great vigor, its abundant production, and its sufficiently high content of sugar make it a beet quite valuable in those countries where the tax is placed upon the amount of sugar made rather than upon the beet. The Brabant sugar beet will give easily 20 tons per acre, and may be made to contain 12 per cent of sugar. Its general appearance is shown by fig. 4.

In France the adoption of legislation placing the tax upon the beet itself has not entirely banished the Brabant variety, but it has succeeded in transforming it into one of greater richness in sugar. This variation of the Brabant beet has been called the French Rich Sugar Beet, and seems destined to have a brilliant future, preserving in its general aspect, and notably in its foliage, many of the characteristics of the Brabant. The French Rich Sugar Beet differs distinctly from the Brabant in the fact that it grows entirely under the soil, is more slender, has a ruddier skin, and more compact flesh. Its yield is superior to the Vilmorin Improved and equal to the Kleinwanzlebener. The content of sugar of this new variety is rarely inferior to 14 per cent. Its general appearance is shown by fig. 5.

Fig. 5.—White French Rich Sugar Beet.

The Imperial sugar beet is one which is largely grown throughout Europe. It has a regular conical outline, with oval-shaped top, and its leaves have rather short stems. There are different varieties, such as the Old Imperial, Improved White Imperial, and the Improved Rose Imperial. Other varieties of beets largely grown are the Electoral,

the Improved Elite, the Improved Imperial Elite, the Imperator, Olive Shaped, the Excelsior, etc.

Following are the names of some of the firms producing high-grade beet seed of the above named and other varieties in Europe:

Vilmorin, Andrieux & Co., Paris.
Dippe Bros., Quedlinburg, Germany.
Carl Schobbert & Co., Quedlinburg, Germany.
Desprez, Père et fils, Cappelle, par Templeuve (Nord) France.
G. Schreiber & Son, Nordhausen, Germany.
Klein & Soukoffsky, à Bielany, Poste Beresovka, Podolien, Russia.
S. L. Ziemann, Quedlinburg, Germany.
Otto Breustedt, Schladen-am-Harz, Germany.
F. Demesmay, Cysoing (Nord), France.
Schlitte & Co., Aumühle bei Gorsbach, Germany.
H. Hornung & Co., Frankenhausen, Germany.
Heinrich Mette, Quedlinburg, Germany.
C. A. F. Degering, Quedlinburg, Germany.
Ladislaus Mayzel, Brzozówka, Post Stopnica, Russian Poland.
Martin Grashoff, Quedlinburg, Germany.
Adolph Strandes, Rittergut Zehringen bei Cöthen (Anhalt), Germany.
Association Maurus Deutsch, 8 Rue Lafitte, Paris.
M. Knauer, Gröbers, Saxony, Germany.

In this country considerable quantities of beet seed have been grown by the Alameda Beet Sugar Company, of Alvarado, Cal., chiefly for its own consumption. It is probable that there are other growers of beet seed in this country, but no definite information concerning that point can be given.

SOIL.

The sugar beet does not require a particular kind of soil for its proper production. In general, soils are described for practical purposes as clayey, sandy, loamy, or alluvial soils; all of these soils will produce beets. The black prairie soils also have been found, with proper cultivation, to produce excellent beets. Perhaps the best soil may be described as a sandy loam; a soil containing a happy equilibrium between organic matters, clay, and sand.

In general it may be said that any soil which will produce a good crop of Indian corn, wheat, or potatoes will, under proper cultivation, produce a good crop of sugar beets. The soil on which sugar beets are grown, however, should be reasonably level, and this being the case it should be well drained. Natural drainage on level soil being somewhat deficient, it is advantageous that tile drainage be practiced. It would be difficult to grow sugar beets on level land without good drainage, especially in a rainy season.

FERTILIZATION.

Happily, in most American soils there is still sufficient natural fertility to produce a good crop of sugar beets; whereas in the soils of Europe, where sugar beets have been grown for years, the farmers must depend on fertilizers to insure a remunerative crop.

Two kinds of fertilizers are employed: stall manure from the farm, and artificial manure generally known as commercial fertilizers. For general purposes, stall manure is desirable. It should be applied, in a well-rotted condition, in the autumn before the ground is plowed. The quantity per acre depends, of course, on the fertility of the soil; but in any case it is not best to apply a very heavy dressing. In poor soils it is best to apply the fertilizer for several years in succession, rather than to apply enough at once to bring it up to the required state of fertility. Too copious an application of stall manure is apt to produce overgrowth in the beets, which makes them ill suited to the manufacture of sugar. If the fertilizer be applied in an unrotted condition, it is apt to seriously injure the crop in case of dry weather.

Of commercial fertilizers three classes are employed containing, respectively, nitrogen, phosphoric acid, and potash. In some instances these three elements are found combined in the same commercial fertilizer. Nitrogenous manure should be applied with great care to sugar beets. It tends to produce a very heavy growth of the beet, and thus to diminish its content of sugar. Potash and phosphoric acid can be applied with great freedom to beet fields; in general they act much better in conjunction than when applied separately.

The principles of fertilization depend upon the fact that a soil of good quality should have returned to it all that the harvest has removed, and a poor soil be supplied with those elements in which it is deficient.

Nothing can be more certain than that a soil to which this restoration is not fully made will gradually lose its faculty to produce plants in normal quantity and composition. Culture experiments with artificial liquid manures have not been carried so far with the beet as with some other plants, and therefore the dependence between the composition of such liquids and the evolution of the beet has not yet been determined. The basis is also wanting whereon the direct working of the manure on the beet can be predicted; and here is met the well-known difficulty of getting the manures into those layers of the soil from which the beet chiefly draws its supplies of mineral plant foods.

PRECAUTIONS TO BE OBSERVED IN APPLYING STABLE MANURE.

Since experience has taught that beets raised on fields freshly fertilized with stable manure are inferior for purposes of manufacture, the rule has long been established that not the beets, but the previous crop should be fertilized with this material, or that the beets should be raised in rotation as the second or even third crop. Unfortunately this rule, so important to the factories, is not always observed, and as a consequence of heavy manuring large crops have been produced, but at the cost of diminished sugar content or lessened price. This rule applies especially to stable manure and night soil, as well as to Chile saltpeter, the misuse of which has produced such serious consequences for factories, but not to phosphatic manures, which usually exert a favorable influence upon the crop.

QUANTITIES OF PLANT FOOD REMOVED FROM THE SOIL.

The constituents to be taken into account in the necessary restitution to the soil of the elements removed by beets are potash, phosphoric acid, magnesia, and nitrogen. Following are the quantities of these constituents in 1,000 pounds of beets and beet leaves, determined by numerous analyses:

Constituents.	Roots.	Leaves.
	Pounds.	*Pounds.*
Potash	3.3	6.5
Phosphoric acid	0.8	1.3
Magnesia	0.5	3.0
Nitrogen	1.6	3.9
Total ash	7.1	18.1

It will be seen from the relation between the roots and leaves that for equal weights the amounts abstracted by the latter are considerably greater and deserve especial consideration in case the leaves are used for cattle food. From this point of view the leaves should be left in the field. It is certain that otherwise complete restitution is attended with some difficulty. The form in which the above-mentioned plant constituents shall be returned to the soil is well established for phosphoric acid and magnesia, and partly for nitrogen. Superphosphates, with greater or less content of phosphoric acid, or with addition of a nitrogenous element, and basic phosphatic slags, are of universal application. As has been shown by direct investigations, the magnesia is nearly all returned in the press cakes from the factory, though a more uniform distribution than is thus secured is much to be desired.

The soil ingredients most essential for the successful production of sugar beets are nitrogen, phosphoric acid, potash, lime, and magnesia.

Most soils contain a sufficient quantity of magnesia, and the press cakes from the factory, which should be returned to the soils, will supply any deficiency. The same is true in regard to lime, although there are some soils in which the supply of lime is naturally deficient. Such soils would be benefited by an application of land plaster, burned lime, phosphatic slags, or ground shells. Phosphoric acid and potash are supplied in the form of ordinary commercial fertilizers: the phosphorus as ground bone, superphosphate, and basic slag; and the potash as kainite or other salt. Of the various potash compounds found in natural deposits, all are useful. Preference is due only to compounds with organic substances. Consequently the molasses, or its residue after distillation, and the liquors of the molasses working processes, all rich in potash, are themselves very valuable materials for potash fertilization, and should be carefully preserved for such use. It must not be supposed, however, that the demand for potash will be satisfied by returning to the soil the molasses from the crop of beets in the form of waste products. Aside from the leaves, for which if taken from the field a largely increased potash return must be made, the molasses itself does

not represent the entire amount of potash taken. Factories which produce raw sugar sell with it also potash, and in all factories the waste waters carry away potash compounds sufficient to account for the difference between the amount of potash in the beets and in the molasses.

Phosphoric acid is best supplied in the form of ground bone, superphosphate, or basic slag from steel factories.

Nitrogen may be supplied in the form in which it exists in ground bone or from the refuse of the slaughterhouses in the form of dried blood and tankage, or as cotton-seed meal or oil cake, or as nitrate of soda, sulphate of ammonia, etc. The simultaneous application of stall manure and nitrate of soda is not advisable by reason of the possible loss of nitrogen due to the development of denitrifying ferments.

As to the relation which the quantity of material returned to the soil should bear to the quantity abstracted by the beet it may be said in general that it is desirable to return as much nitrogen, from one and a quarter to one and a half times as much potash, and two and a half times as much phosphoric acid as have been removed by the roots. Greater additions of potash and phosphoric acid have no disadvantageous effects upon the crop. Direct investigations in regard to the relation between the sugar and potash in consecutive crops for many years have failed to give the least ground for a contrary conclusion. But it must not be expected, on the other hand, that increasing fertilization, especially potash fertilization, will produce proportionately increasing crops, as has been asserted by some.

EFFECT OF NITROGENOUS MANURES ON THE QUALITY OF THE BEET.

The opinion has generally prevailed among beet growers during late years that heavy nitrogenous manuring, especially with nitrate of soda, produces no injurious effect on the quality of the beet. This opinion was based on the fact that in such beets the sugar per cent was only slightly diminished. Nevertheless the quality of a beet may be impaired even with little or no diminution of the sugar content by reason of the increase of the percentage of nonsugars present.

In this respect it has been shown that heavy manuring with nitrogenous substances greatly injures the quality of the beet for sugar-making purposes. The apparent coefficient of purity of the juice is also frequently misleading, since no account is taken of the nature of the nonsugars present.

The real purity of the beet is also to be distinguished from the apparent purity of the juice. The real purity of the beet is obtained by dividing the percentage of sugar in the beet by the total solid matter in solution therein; the apparent purity of the juice by dividing the percentage of sugar therein by the apparent percentage of solids as indicated by the specific gravity. Judicious fertilizing with nitrate of soda, however, is beneficial, and this form of nitrogenous fertilizer is in many respects the best known for beets.

ROTATION.

Beets do best after wheat or some other cereal. It is true that soils on which beets have not been grown, as the soils of this country, may produce beets for several years without harm. Nevertheless, proper rotation is always desirable.

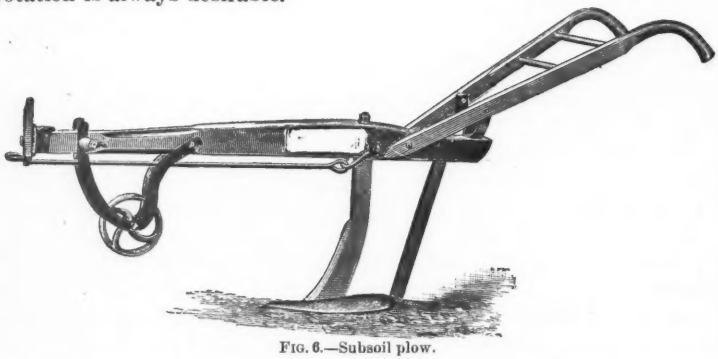

FIG. 6.—Subsoil plow.

A good scheme of rotation is, first, wheat; then beets; then clover, one crop of which is cut for hay and the second crop plowed under; then potatoes, wheat, and beets in the order mentioned. By this method, and a judicious use of stall manure and commercial fertilizers, the fertility

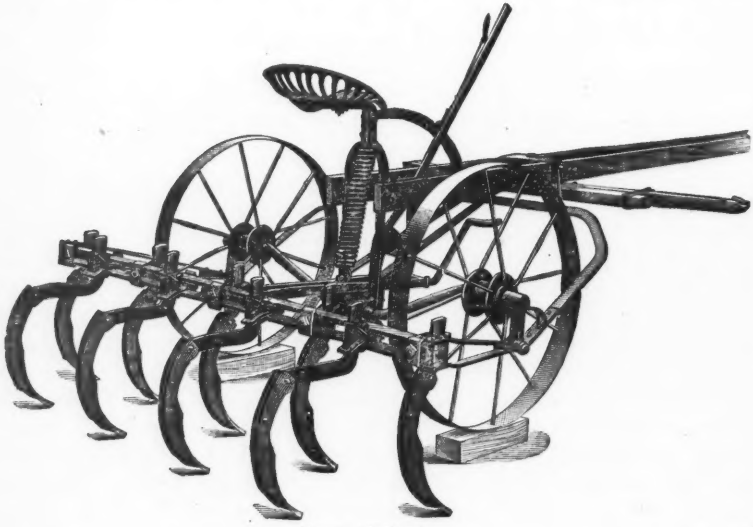

FIG. 7.—Cultivator.

of the soil can be maintained and even increased. Beets should follow wheat or other cereal crop, because this crop, being harvested early, leaves the ground ready for late autumn plowing, a prerequisite to successful beet culture.

PREPARATION OF THE LAND FOR PLANTING.

The field in which beets are to be planted should be selected and plowed in the late autumn to the depth of at least 9 inches. The plow in each furrow should be followed by a subsoiler, which will loosen the soil

FIG. 8.—Seed drill.

to the depth of 6 or 7 inches more. A convenient subsoil plow is shown in fig. 6. Each field to be planted in beets should thus have the soil prepared by thoroughly loosening it to the depth of from 15 to 18 inches.

FIG. 9.—Seed drill.

The land, being exposed through the winter, becomes quite mellowed, and in the spring can be prepared for planting by a simple treatment of the surface. This is done after plowing by a thorough surface

cultivation until the surface of the soil is reduced to perfect tilth. The large cultivator shown in fig. 7 can be conveniently used for this purpose, followed when necessary by a harrow and roller. It is desirable, however, that each portion of the field to be planted should be thoroughly prepared immediately before the planting takes place. For instance, if the planting is to be made on a given day, the soil should be thoroughly prepared on the previous day. Thus all weeds and grasses which have started to grow are killed, and the beets have an even chance with the weeds for growth. If, on the other hand, the soil be prepared a week or even a few days before planting, the weeds and grasses get a good start, and it is difficult to free the beets therefrom.

FIG. 10.—Hand seed drill.

PLANTING.

The beets may be planted either by hand or by drill. Hand planting may be practiced when a very small plat is to be put in beets, but where a field embracing several acres is to be planted it is not convenient. In such cases planting by drill is best. Almost any garden drill can be adapted to use with beet seed. Special drills for sugar-beet seed are made by many manufacturers of agricultural implements. One is shown in fig. 8. The form of drill represented in fig. 9 may also be used. In planting by drill it is necessary to use from 15 to 20 pounds of seed per acre; in planting by hand from 10 to 15 pounds will be found sufficient.

Another very convenient hand drill, which is especially fitted with a beet-seed dropping apparatus, is shown in fig. 10. This machine marks and excavates the row, drops the seed at any required distance, and covers it.

The beets should be covered to the depth of from one-half to 1½ inches, according to the state of the soil. If the soil be moist and in excellent condition, the beet seed should not be covered more than half an inch. If, on the other hand, the soil be very dry and early rains are not probable, the seed should be covered to the depth of 1½ inches.

In large cultures it is often important to be able to plant more than one row of beets at a time. For this purpose the planter shown in the accompanying figure (11) is convenient. The machine is adapted to planting four rows at a time. The runners can be adjusted at any distance from 16 to 20 inches apart and the quantity of seed planted can be varied from 15 to 25 pounds to the acre.

In planting by hand or by drills an effort should be made to distribute the seeds singly and at equal distances apart.

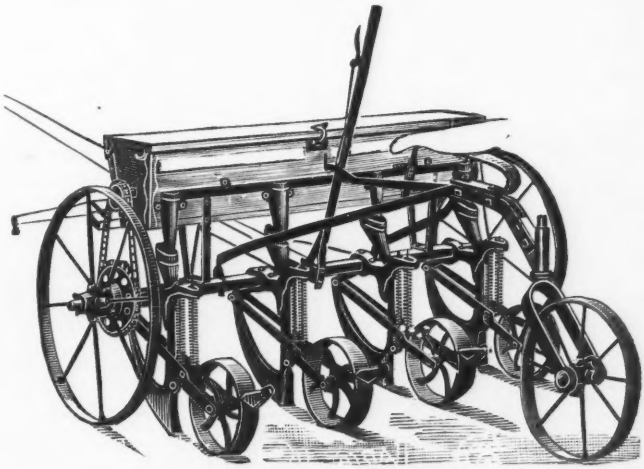

FIG. 11.—Seeder for four rows.

TIME OF PLANTING.

Beets should be planted as early in the spring as possible. Experience has shown that the early planted beets almost uniformly produce a larger yield and with a higher content of sugar than the late planted. No exact date can be fixed which would be suitable to all localities. In most of the localities in the beet area of the United States it will not be found practicable to plant earlier than the first week in May. In exceptional seasons a part of the sowing may be accomplished in April.

On the Pacific Coast, especially in central and southern California, the sowing can take place at a much earlier date. At Chino planting has been practiced in December with favorable results. In 1895 one acre of beets planted in the autumn yielded at the rate of 12½ tons per acre, with an average sugar content of 15.2 per cent and a purity

of 81.5. In the same field 8 acres planted in the spring yielded only 5 tons per acre, with an average sugar content of 14.7 and a purity of 80.5. It was observed, however, that the autumn-planted beets had a higher content of marc than those planted in the spring. Under date of January 4, 1897, the agricultural manager of the Chino Beet Sugar Factory wrote that he had planted 5 acres of beets on the 21st of December and that they were then well out of the ground.

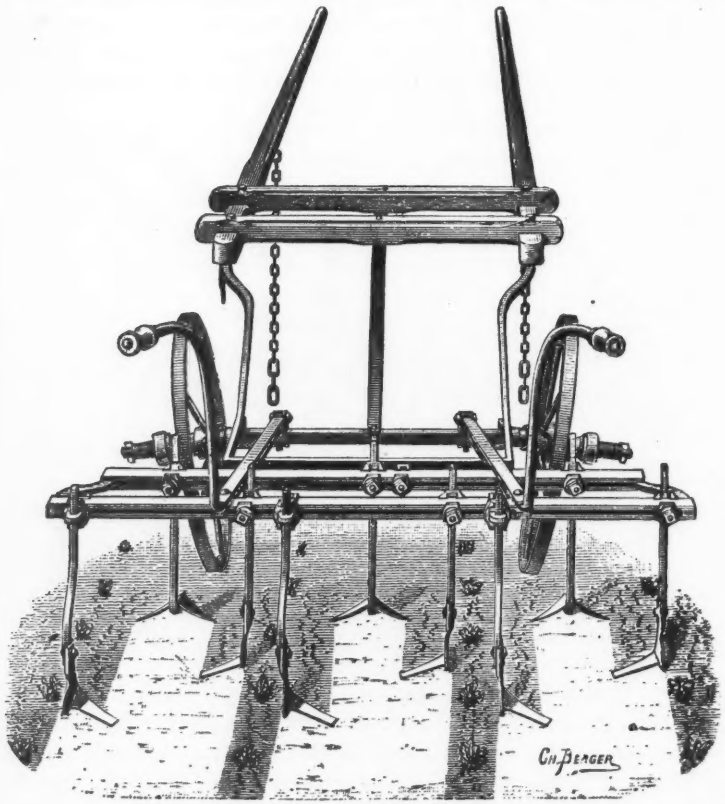

FIG. 12.—Horse hoe.

He further stated it to be the intention of the company to continue the experiments of autumnal and winter planting on a more extensive scale, and to plant from 50 to 100 acres in the autumn of 1897 for the harvest of 1898. In this connection it must be remembered that the climatic conditions of the Chino Valley are almost unique for beet-sugar production, and the experience there obtained would not be applicable to beet sugar regions in general.

CULTIVATION.

As soon as the beets are large enough to mark the rows, cultivation with the horse or hand hoe may be commenced. Cultivation must not

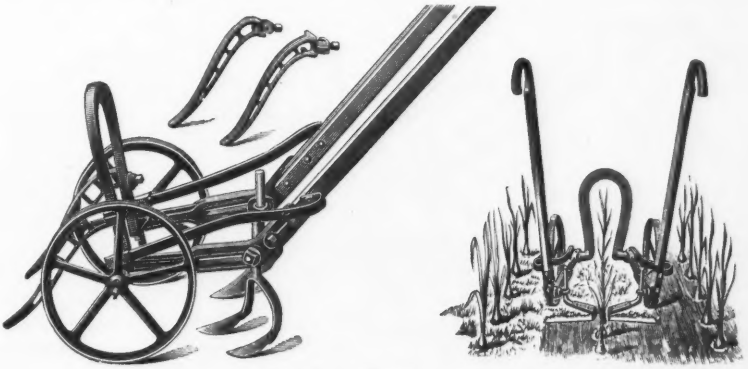

FIG. 13.—Hand hoes.

be postponed, except for unfit condition of the soil, if the grass and weeds appear above the ground at the same time with the beets.

When large fields are cultivated, the horse hoe, a model of which is

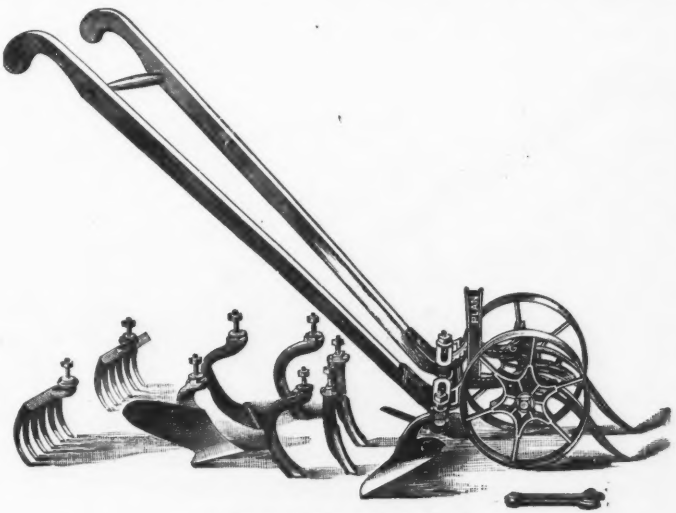

FIG. 14.—Cultivator for beets.

shown in fig. 12, may be used. For smaller fields a similar apparatus drawn by hand may be employed. Convenient instruments of this kind are shown in figs. 13 and 14. This plow frees the spaces between

the rows of beets from weeds and the guard prevents the growing beets rom being covered by the loose soil.

When the beets show four leaves the process of thinning should take place. If the rows be 18 inches apart a vigorous plant should be left

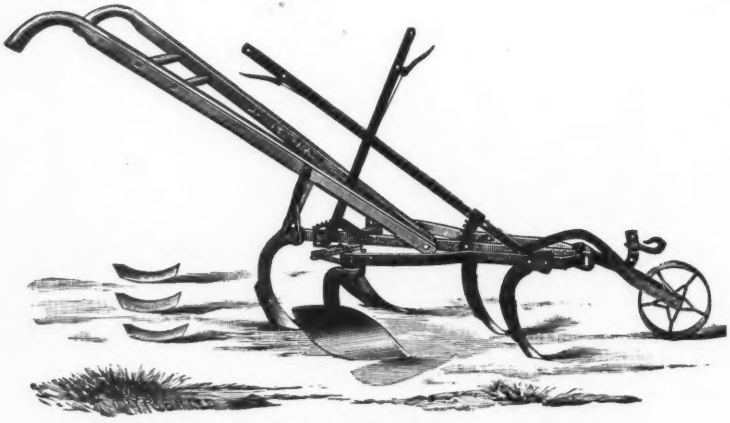

FIG. 15.—Deep cultivator.

every 8 or 10 inches. Careful selection should be made and all the puny plants destroyed. It is better to save the vigorous plants even if regular intervals are not preserved, but no space should be left greater

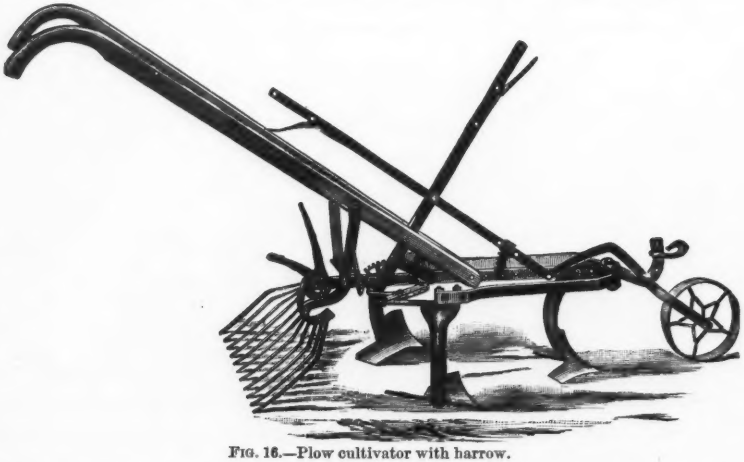

FIG. 16.—Plow cultivator with harrow.

than from 12 to 15 inches in extent. Much of the thinning work can be done with a narrow hoe, but where the plants are very close together, at the place where the preserved plant is to grow the work must be done by hand. It is well to give a thorough hand hoeing at the time of

thinning, and the subsequent cultivation, in most seasons, may be carried on with horse power.

When the beets are more advanced a few deeper cultivations may be desirable, and for these any good narrow cultivator may be used for

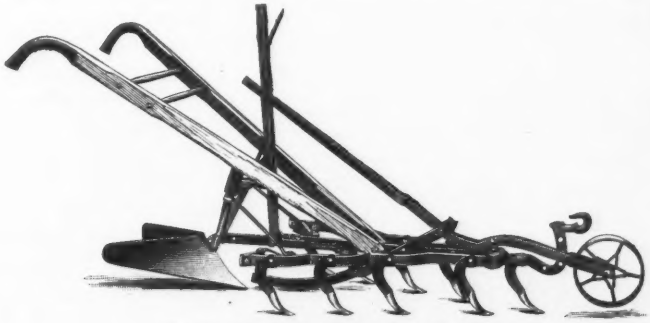

FIG. 17.—Beet cultivator for irrigated lands.

single rows or wider ones for double rows. The instruments shown in figs. 15 and 16 will be found suitable to this kind of work.*

The cultivation in all cases should be conducted for the double pur-

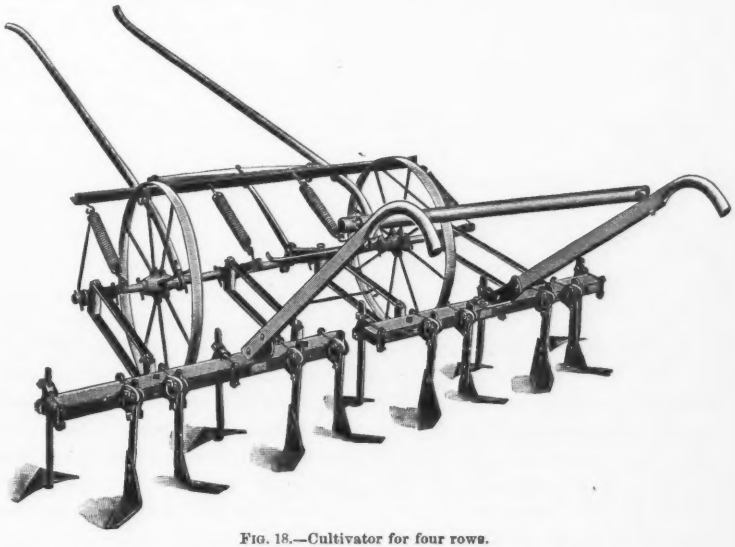

FIG. 18.—Cultivator for four rows.

pose of keeping the beets entirely free of weeds and for preserving

* Many of the illustrations of cultivators are from electrotypes kindly furnished by S. L. Allen & Co., of Philadelphia, the Moline Plow Co., and the Deere-Mansur Co., of Moline, Ill.

the proper tilth of the surface of the soil. It may be said that at least once a week during the period of growing, lasting from six to eight weeks, the beet field should be cultivated. If the season be very dry, more frequent cultivation will be found useful. The final cultivation should leave the soil practically level. During cultivation care should be taken not to injure either the leaves or the root of the beet, and when the foliage of the growing crop begins to cover well the surface of the soil cultivation may be suspended.

In growing beets with irrigation a cultivator which will prepare the furrow for conducting the water over the field is important. Such a machine is shown in fig. 17. In this instrument the plow shown in the rear of the cultivator teeth forms the required furrow and can be set at any required depth. In ordinary cultivation, the brush harrow shown in fig. 16 can be inserted in place of the plow.

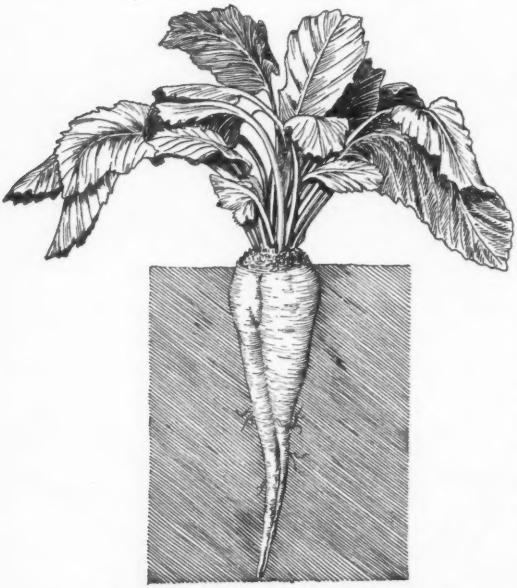

FIG. 19.—Correct position of a mature beet in the soil.

In the cultivation of large areas, an implement adapted to four rows of beets is desirable. Such an implement, however, can not be advantageously used, except in those cases where the beets have been sown with an implement of similar capacity. The cultivator shown in fig. 18 is suitable for use on fields which have been planted with the seeder shown in fig. 11. The gangs of plows in this instrument are easily handled by a spring lift, and by reason of a peculiarity of construction run steadily and adapt themselves exactly to the rows, so that the operator needs only to watch a single row. Different kinds of implements for cultivation can be easily attached so that the instrument can be used as a plow, a cultivator, or a harrow.

POSITION OF THE BEET IN THE SOIL.

It is important not only that a sugar beet should be of a proper size and shape, but also that it be grown in such a manner as to secure the

protection of the soil for all of its parts except the neck and foliage. The proper position for a beet to occupy in the soil at the end of growth is shown in fig. 19. This position can only be secured for the beet by growing it in a soil sufficiently pervious to permit of the penetration of the taproot to a great depth. It is for this reason that subsoiling in the preparation of a field for the growth of sugar beets is of such great importance. If the beet, in its growth, should meet a practically impervious subsoil at the depth of 8 or 10 inches, the taproot will be deflected from its natural course, lateral roots will be developed, the beet will become disfigured and distorted in shape, and the upper portion of it will be pushed out of the ground. Experience has shown that the content of sugar in those portions of a beet which are pushed above the soil is very greatly diminished.

COST OF GROWING BEETS.

The cost of growing an acre of beets depends on so many varying factors as to render it impossible to give an estimate which is reliable for every locality. The differences in rent of land, cost of labor, methods of culture, etc., require that any estimate which may be given should be revised for almost every series of conditions. The following estimate of maximum cost per acre is based on the supposition that land is worth $75 per acre, labor $1 per day, the yield 15 tons per acre, and that the distance to the factory is not greater than 3 miles:

Rent of land	$5.00
Plowing, subsoiling, and preparing for planting	5.00
Fertilizers	10.00
Cost of seed	2.25
Planting	1.75
Hoeing and thinning	6.00
Cultivating with horse hoe five times	5.00
Harvesting	5.00
Topping	12.00
Delivering to factory	7.50
Total	59.50
Value of 15 tons, at $4.50	67.50

In the above estimate has been included the cost of the best culture and a reasonable application of fertilizers. It is probable that the actual cost to our farmers for the first few years of the beet industry will not exceed $45 or $50 per acre and in many instances will fall below these figures. The price paid for the beets is dependent on many local considerations, but chiefly on the selling price of sugar and the richness of the beet.

It is reasonably certain, accidents of season aside, that a net profit of from $8 to $15 per acre may be expected from the proper culture of the sugar beet in localities near a factory when all the conditions of the best methods of culture are fulfilled.

In contrast with the above estimate, the actual figures submitted by Mr. J. Thomssen, of Hall County, Nebr., in a letter published in the

Prairie Farmer, on the 3d of January, 1891, are given. The cost is given for a field of 5 acres, and the items are as follows:

Fall plowing, at $1 per acre	$5.00
Plowing in spring, at $1.25	6.25
Rolling twice, once before and once after planting	1.50
Planting by hand, at 75 cents per acre	3.75
Cultivating with hoe, at 75 cents	3.75
Thinning, at $10	50.00
Hoeing by hand three times and weeding necessary at time of hoeing	90.00
Cultivating by horse twice, at 75 cents	7.50
Running over with hoe to clear from remaining weeds	3.75
Total	171.50

Dividing this by 5 gives a total of $34.30 per acre.

As will be seen from the above, Mr. Thomssen makes no allowance for the rent of the land, used no fertilizers, and gives no estimate of the price of seed and of the expense of harvesting and hauling to the factory. But his field was hoed by hand three times, which with the proper implements is more than is necessary, one good hand hoeing being as a rule sufficient.

The average cost per acre of raising sugar beets in France is given by a French statistician as follows:

Farmyard manure	$28.00
Commercial fertilizers	12.00
Spreading manure	.60
Spreading fertilizers	.25
First plowing	1.60
Harrowing and rolling after plow	.64
Plowing and subsoiling	4.60
Two scarifyings	2.00
Two harrowings	.64
Two rollings	.64
Cost of seed	3.00
Sowing of seed	.80
Harrowing and rolling again	.64
Three times hoeing with horse	2.40
Hoeing by hand	4.80
Harvesting by machine	1.60
Lifting and topping	4.00
Carting to factory	2.40
Total	70.61

To the figures stated are still to be added the rent of land and taxes, $9.40, making a total of $80.01.

The charge for harvesting is very low, from the fact that the topping of the beets is performed by women and children, whose average wages probably do not exceed 15 cents a day, much less than the estimates call for in this country, while the charge for fertilizers is much greater than would be necessary in this country for some years to come. The average yield per acre obtained by M. Du Fay, the author of the above estimate, was 25 tons, showing the value of intensive farming.

Mr. J. B. Henderson, of Alameda, Cal., reports the cost of growing and harvesting 10 acres of beets at $614.83, or $61.48 per acre. His farm is 1 mile from the factory. Mr. A. F. Richardson, of the same place, residing 2 miles from the factory, reports the cost of 11 acres at $535.04, or $48.64 per acre.

It is not wise to underestimate the actual cost of growing the beets, for this will lead the farmer to expect large profits which often in practice give way to actual deficits.

HARVESTING.

The time for harvesting varies in different localities. In southern California the beets planted in February are ready for harvesting in August. In general it may be said that beets planted the first week

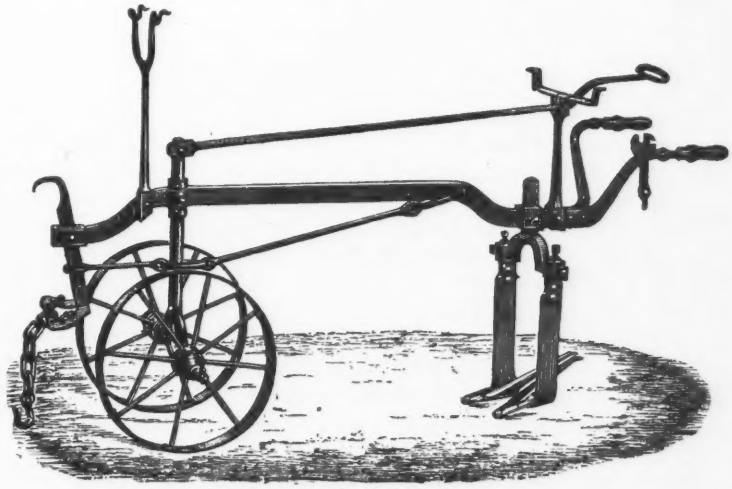

FIG. 20.—Beet harvester for one row.

in May will be ready for harvesting about the first of October. Harvesting should be postponed to as late a date as possible, provided the beets are in no danger of a second growth and are not exposed to a freezing temperature. The leaves of the ripened beet change from a rich to a yellowish green, become drooping and applied closely to the earth, and many of them die. The harvesting is easily accomplished by first loosening the beets in the soil and then removing them by hand. For loosening the beets, the apparatus shown in fig. 20 may be employed. It can be used to advantage only when the rows are perfectly straight and the beets of a reasonably uniform size. The teeth of the apparatus are sunk deep enough into the earth to catch the beet below its middle part. In moving forward the plow catches the beets between its two prongs, which approach more nearly together in the rear, and

on account of the angle at which the teeth are fixed the beets are lifted and the tap roots broken. After the passage of the harvester the beets are easily lifted out of the ground by means of their leaves.

The next operation consists in removing the neck. This is done by a large knife and the top of the beet, called technically its neck, is cut off so as to remove, with the top, that portion of the beet to which the stems of the leaves have been attached.

The object of removing this portion of the beet is to prevent the mineral salts, which have accumulated in large quantities therein, from entering the factory. These mineral salts exercise a very deleterious influence on the crystallization of the sugar, and, therefore, should be removed. They are well fitted for feed or for fertilizing purposes and are of more value when left upon the soil than when removed to the factory. The neck is also much less rich in sugar than the other parts of the root.

The removal of the tops of the beets is a tedious process which, in Europe, is performed by women and children. In this country the process of topping the beets will prove much more expensive than in Europe. It is probable that some mechanical device will be invented by which the beets can be topped, thus saving a large expense. So far as known at the present time, however, this process has not been successfully accomplished by machinery and the topping must still be done by hand.

When the beets are topped they are thrown into piles, and the tops thrown over them as a protection from the sun or frost until they can be delivered to the factory.

The beets are best delivered to the factory in dump carts, which permit of their quick unloading. It is not customary for the farmers to silo their beets except in the simple manner indicated above.

SILOING.

When beets are to be preserved for manufacture during the winter months or for the production of seed, they must be carefully protected against frost. The simplest and the easiest method is to place them in piles and cover them with earth, not too deeply, for if they become too warm in the silo they rapidly lose in sugar content. When first siloed, say, about the 1st of November, they should be covered with only a slight layer of earth; as the cold of winter becomes more intense this covering can be increased. In some localities only a slight covering of straw is necessary to protect the beets, as, for instance, in California. In other localities, such as in the Dakotas, Minnesota, and Wisconsin, it is probable that the beets would have to be covered to the depth of 2 feet, or even more, to protect them from frost.

Siloing is usually done by the factory, as it would be very inconvenient to deliver beets from a distance to a factory in the middle of winter.

In most localities in the beet-sugar region of the United States it is

probable that the harvesting and delivery to the factory could be entirely completed by the middle of November; although in some seasons there would be no danger whatever in leaving the roots in the earth until the 1st or even the 10th of December, while in California there is no danger at all of freezing.

In the construction of large silos due regard must be had for proper ventilation to avoid the danger of heating.

PRODUCTION OF SEED.

The production of seed is one of the most important operations connected with the sugar-beet industry. On the care and skill which are displayed in this process depend the improvement and maintenance of the sugar-producing qualities of the beet. There are many different methods employed for producing seed which will grow the richest sugar beets, but there will be mentioned here only a general outline of the principles which underlie the process. The beets which are to be preserved for seed are called "mothers" and are carefully siloed in the manner already indicated. They are selected at the time of harvesting from specially grown beets or from fields of beets which have shown particularly good qualities on analysis. The size of the roots selected for mothers should be about the average of the best sugar beets, viz, from 20 to 24 ounces. Smaller beets than these might show a higher content of sugar, but it is not wise to produce a race of small beets by selecting the seed from the very smallest and richest beets grown. The weight of the mothers having been decided upon, the beets are next selected for their shape and external appearance. Those regular in shape and smooth in external form are to be preferred. Roots of irregular shape or with more than one tap root should be rejected.

The beets to be preserved for mothers are harvested with unusual care to avoid injury. The neck is not cut away, but the leaves are removed by cutting off the stems without injuring the neck of the beet.

The siloing should be of such a nature as to entirely protect the beets from frost and yet prevent their growth in the silo until the spring. The beets are removed from the silo at an early date in the spring and are immediately subjected to analysis for the final selection. In the early days of the beet industry the beets were selected almost solely on account of their specific gravity. A brine of a given strength was made, and the beets, thoroughly cleaned of dirt, were thrown into this brine. Those which would sink were selected as mothers, while those that would swim were rejected. At the present time the final selection depends upon the actual determination of the density of the juice of the beet which is to be selected as a mother and the estimation of its content of sugar. For this purpose a cylindrical piece of the beetis removed by an appropriate instrument cutting diagonally through the center of the root. This piece may weigh 2 ounces or even more, and its removal does not injure the beet for germinating purposes. The

juice is expressed from this piece, and its specific gravity determined by weighing in it, at a given temperature, a silver button of known weight.

The sugar content of the juice is next determined by means of the polariscope. By means of these two data the qualities of the beet for the production of seed are determined and also the coefficient of purity; that is, the number obtained by dividing the percentage of sugar in the juice by the percentage of solid matters as determined by its specific gravity. In mother beets this number is found somewhere between 80 and 90. The actual method of selection may be illustrated as follows:

The operator determines beforehand his standard, which in most cases will consist of a juice containing from 16 to 18 per cent of sugar with a purity of 85. The beets are analyzed separately, and are at once divided into two great classes, namely, those in which either the content of sugar or the purity falls below the fixed figure, and, second, those in which these two numbers are equal to or exceed the fixed figures. It is sometimes customary to divide these two classes into two portions, viz, those roots in which the numbers are equal to or slightly above the standard, and, second, those which show exceptional richness. It is also customary to number each beet, and the number, which is cut into the skin of the beet, will remain legible even after the seed has ripened. Some of the producers of sugar-beet seed preserve the product of seed from each beet by itself, and do not use it to inaugurate the production of seed for commerce until it has received an additional year's trial.

By this method of careful, scientific culture the sugar beet has been raised to its present high standard of excellence, and is only maintained at this standard by constant supervision, such as has been indicated.

The sugar-beet seed produced by the above method is not sold for planting fields, but is used solely for the production of the seed of commerce in the fourth or sixth year from the parent, as the case may be.

DOMESTIC PRODUCTION OF BEET SEED.

The commercial production of beet seed of pure pedigree and high grade has not been practiced to any extent in this country. The Alameda Sugar Company, and perhaps others, have grown large quantities of beet seed for domestic use, but without any attempt to sustain or increase the sugar content by scientific methods. During the continuance of the experiment station at Schuyler, Nebr., a system for the production of beet seed of exceptionally high grade was inaugurated, embodying all the best features of the methods practiced in Europe. In the spring of 1893, 6,370 beets, which had been carefully selected on account of their physical characteristics and preserved in a silo over winter, were subjected to an analysis by removing a cylindrical core from each one and subjecting the expressed juice therefrom to a chem-

ical examination. Allowing for the deterioration in sugar content which the beets had suffered during storage, the beets were classified by the analysis as follows:

Variety.	No. I grade (sucrose 18 per cent upward).	No. II grade (sucrose 15 to 18 per cent).	No. III grade (sucrose 12 to 15 per cent).
	Beets.	*Beets.*	*Beets.*
Original Kleinwanzlebener	36	465	448
Dippe's Kleinwanzlebener	6	483	1,176
Vilmorin's Improved	8	600	784
Lemaire			476
Desprez			168
Elite Kleinwanzlebener	7	210	224
	57	1,758	3,276

The following statement gives the proportion of the beets analyzed which was eligible for propagation uses:

Number of beets of all grades accepted for seed production	5,091
Number of beets of all grades rejected for seed production	1,179
Total	6,270

By reason of the abolition of the experiment station the beet seed produced was sold to the highest bidder for a sum which would have brought for an acre under cultivation $172.60.

PRODUCTION OF COMMERCIAL BEETS FROM A SINGLE HIGH-GRADE BEET.

In the case of any given variety let it be assumed that a beet is found of good size and typical form, and exceptionally rich in its sugar content and the purity of its juice. The production of beets on a commercial scale from this single individual is accomplished as follows: The beet is preserved over winter and planted in the spring for the purpose of producing seeds. The seeds thus obtained are carefully freed from all imperfect and defective individuals, and planted the second year for the production of beets. Several hundred beets will likely be produced from this sowing. All of these beets which are of proper size and good form are preserved during the winter. In the third spring they are all carefully analyzed and those which reach or exceed a given standard are planted for the production of seed. It is probable that during this third season several thousand beets will be produced. All those which are of typical size and shape are preserved over the winter and the fourth spring are planted without analysis, and the seed which they yield will be of sufficient quantity to be used in the fifth year for the production of sugar beets for the factory. It is seen by the above statement that at least five years are required for the production of seed for commercial purposes from any high-grade individual beet which may be selected for the purpose.

COMPARATIVE VALUE OF DOMESTIC AND FOREIGN GROWN SEED.

In the experiments conducted at the station at Schuyler during the season of 1893 a comparison of the beets grown from domestic and imported seeds was made. The plants from the native-grown seed seemed to have a higher vitality and to be better suited to the climatic conditions of the locality than those grown from imported seeds. They showed during the growing season a more abundant foliage and a better development of roots. This higher vitality and quality of the beets grown from domestic seed illustrate in a forcible degree the advisability of the production of our beet seed at home. Even granting that seeds produced in foreign countries have the same high qualities, it must be admitted that their vitality is in danger of being very much diminished during shipment to this country. The moist air of the holds of the ships in which they are transported often produces moldiness and incipient germination, which tend to greatly diminish their value. Not only did the beets produced from the home-grown seed have a higher percentage of sugar, but they also afforded a higher yield per acre, as determined in the experiments at Schuyler. The mean tonnage per acre from the home-grown seed was 21.1 and from the imported seed 17.9. The mean pounds of sugar produced per acre from the home-grown seed was 5,891 and from the imported seed 5,185. This shows an increase of about 12 per cent in the actual quantity of sugar per acre when domestic seed was used. These data should be carefully studied by all those who are interested in the production of beet sugar in this country. Perhaps the time has not yet come for the inception of such a work, but it is evident that it will not be long before there will be a demand for the establishment in this country of a plantation or plantations devoted exclusively to the production of beet seeds on the most approved scientific principles.

The quantity of seed required to plant an acre is about 15 pounds. The approximate number of acres planted to beets in this country during the season of 1897 was 45,236, requiring 678,540 pounds of seed. It is evident that there is already an opportunity for the active operation of a large plantation devoted exclusively to the production of beet seeds for domestic use.

Another point to be considered is that by the importation of foreign seeds there is danger of introducing those fungoid and microbian diseases of beets which have produced such ravages in Europe.

MANUFACTURE OF SUGAR.

The process of making sugar from the sugar beet interests the agriculturist only from secondary considerations, and will be treated in the briefest possible manner to give an intelligent idea of its methods.

The beets are first conveyed to washing tanks provided with suitable apparatus for keeping them in motion and transferring them toward

the end from which the fresh water enters, in order that the whole of the adhering soil, together with any sand and pebbles, may be completely removed. By a suitable elevator the beets are next taken to a point above the center of the diffusion battery, shown in fig. 21, whence

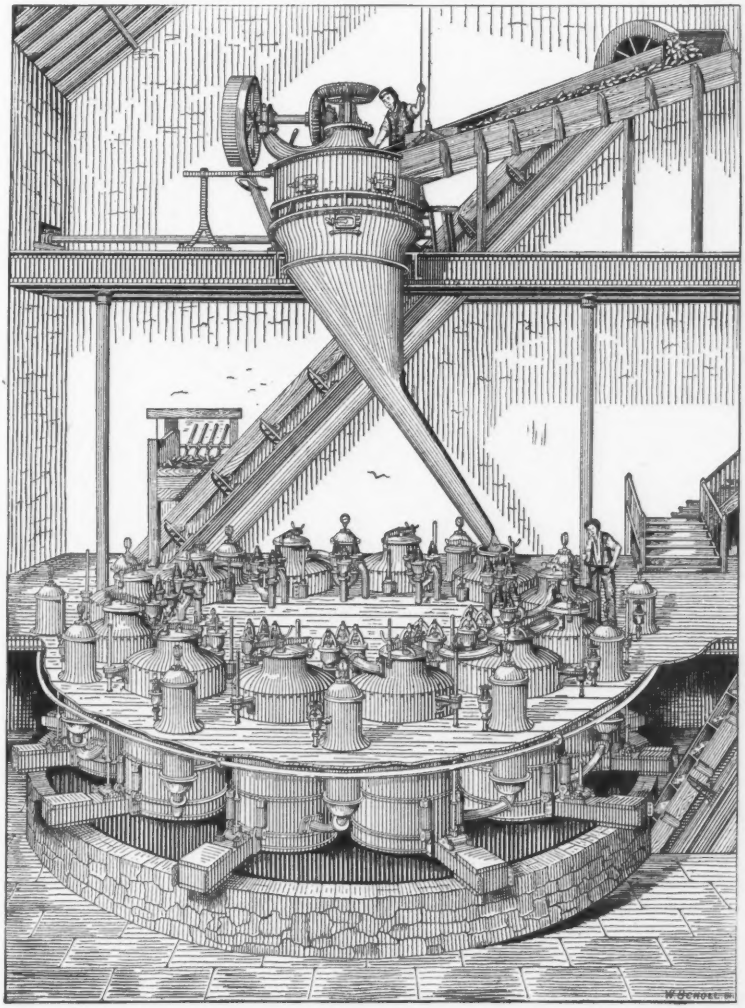

FIG. 21.—Diffusion battery.

they are dropped into a slicing apparatus, by which they are cut into pieces of greater or less length and of small thickness, and of such a shape that when placed in the cells of the battery they will not lie so closely together as to prevent the circulation of the diffusion liquors.

When the cell is full of the sliced beets it is closed and the hot juices from the cell last filled are admitted and allowed to remain in contact with the cuttings for a few minutes. From 10 to 12 cells are thus kept in use. While one is filling another is emptying. The fresh hot water is always admitted to the cell next to be emptied and passes in succession through all the cells under pressure, until it reaches the one last filled. From this cell a quantity of juice is drawn off each time and sent to the clarifiers for purification.

The extracted cuttings are carried through a press by which a portion of the water is removed, and they are then in suitable condition for use as cattle food. The diffusion juices obtained as above described are carried to carbonatation or saturation tanks, where they are treated

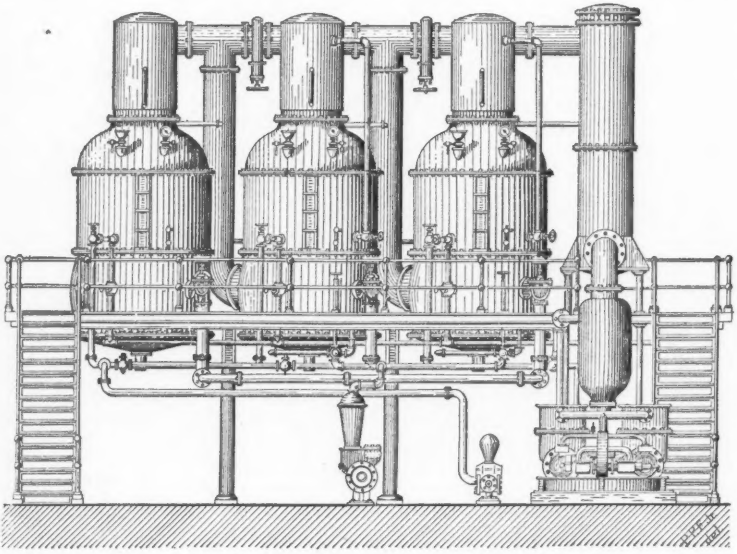

FIG. 22.—Multiple-effect evaporating apparatus.

with from 2 to 3 per cent of their weight of lime and afterwards with carbonic acid until nearly all of the lime is precipitated. The slightly alkaline juices are next passed through filter presses, by which the precipitated lime and other solid matters are removed. The juices pass next to a second set of carbonatation tanks, in which they undergo a treatment in each particular similar to the one just mentioned, except that the quantity of lime added to the second saturation is small as compared with that of the first. The refiltered juices from the second saturation are carried to the multiple-effect vacuum pan and reduced to the condition of sirup.

The multiple-effect evaporating apparatus (fig. 22) consists of a series of pans connected en suite in such a manner as to secure a progressively

higher vacuum in each one. The thin juices enter the first pan, where they are evaporated at a vacuum represented by a column of 8 or 10 inches of mercury. The steam with which this evaporation is effected is usually the waste coming from the engines and pumps of the factory. The vapors generated in the first pan enter the heating pipes of the second one, and are thus utilized in evaporating the somewhat concentrated sirup which is drawn off from the first pan into the second one, where the vacuum is higher, being represented by a column of mercury of from 16 to 18 inches in height. The vapors which are produced in the second pan are in like manner conveyed to the heating pipes of a third apparatus, where the still more concentrated sirups from the second pan are conducted and evaporated at a still higher vacuum of from 22 to 26 inches of mercury. Sometimes a fourth pan is employed, but the arrangement is fully illustrated by the above example. It is easy to see by the arrangement above noted that the evaporation of the thin diffusion juices to a heavy sirup is accomplished with the greatest economy, steam being admitted only into the first pan, and the rest of the operation being automatic, aided only by the pumps producing the vacuum. The sirups thus produced are converted into sugar in the following manner:

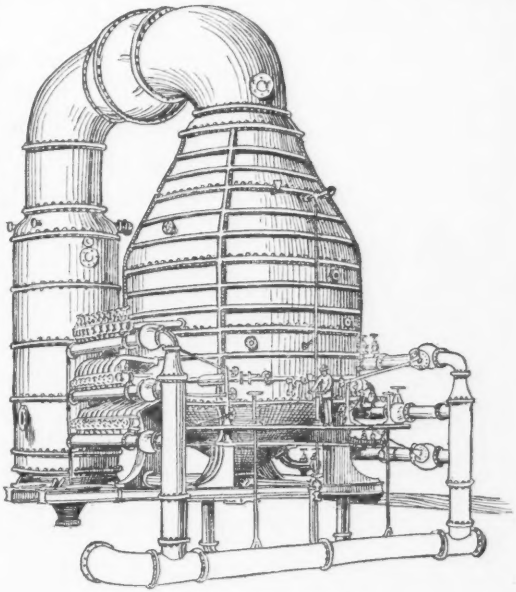

FIG. 23.—Vacuum strike pan.

A portion of the sirups is placed in an evaporating apparatus called the strike pan. This apparatus is very large, usually of a pear shape, with somewhat straight sides, and provided with a series of coils, one above the other, to which the steam can be admitted at will. The admission of steam is always so regulated that it is not allowed to enter any of the coils above the surface of the liquid in the pan. The portion of sirup first introduced is evaporated until it reaches a point of consistency which will permit of the formation of crystals. In this condition, if a portion of fresh sirup be quickly introduced the whole mass in the pan

becomes charged with exceedingly fine crystals of sugar. By careful manipulation and the introduction of new quantities of sirup from time to time these crystals are made to grow. As the pan becomes full successive coils of the steam pipes are brought into use, so that the boiling surface of the pan is gradually increased in proportion to the volume of its contents. In the course of a few hours the skilled sugar boiler will find that the pan is full and that the crystals have grown to the proper size. The mass in the vacuum pan at this stage is extremely heavy, consisting of a dense mass of sugar crystals mixed with a quantity of molasses greater or less in amount, as the juices from which the sugar is made are more or less pure. The illustration of the vacuum pan (fig. 23)

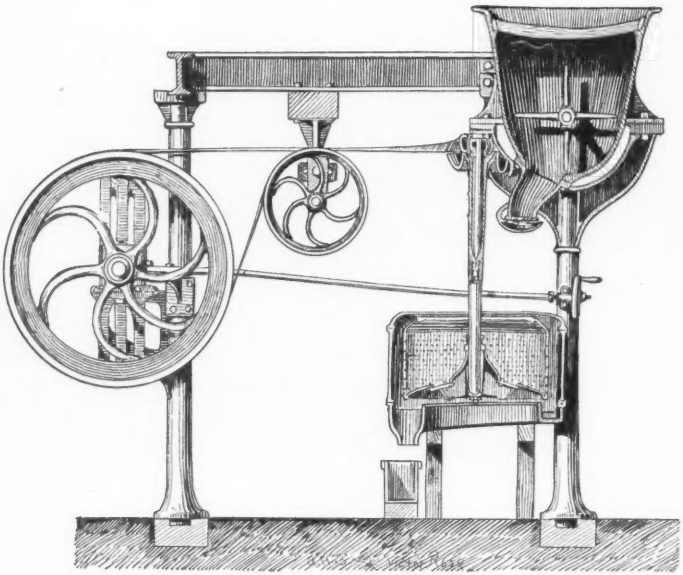

FIG. 24.—Centrifugal apparatus.

is from a photograph of a large pan, 17 feet in diameter and 42 feet high, intended for refinery use. This pan turns out 1,000 barrels of sugar at each strike, and the time required for boiling is about three hours. It is constructed on exactly the same principles as the smaller pan employed in beet-sugar factories. In boiling sugar in a vacuum pan, if the highest possible yield is desired and no objection arises to the formation of soft crystals, a very high vacuum, equivalent to 29 inches of mercury at the sea level, is employed. At this vacuum the sirups boil at a temperature of from 112° to 120° F. If harder crystals, giving a somewhat less yield, are desired, as in the case of making granulated sugars, a lower vacuum, namely, from 24 to 26 inches, is employed.

The sirups are reduced in the vacuum strike pan into sugar called

massecuite, which contains from 6 to 10 per cent of water. This is then carried directly to the centrifugals, where the molasses is separated.

The construction of the centrifugal apparatus is shown in fig. 24. A lining of wire gauze permits the molasses to pass outward under the impulse of the centrifugal motion, while it retains all the crystals of sugar except those fine enough to be entrained with the escaping liquid. The uncrystallized sirups together with the water are separated from the sugar by the centrifugals, and form the molasses. The molasses is either reboiled and a second crop of crystals obtained, or it is treated in various ways for separating the sugar which it still contains. One of these methods which has come into general use is known as the Steffen process. In this method the molasses is diluted with water cooled to a low temperature and treated with fresh-burned, fine-ground lime. The sugar in these conditions forms a chemical compound with the lime which is separated from the other constituents of the molasses by means of a filter press. The lime sucrate thus secured is beaten up to a cream with water, the lime precipitated with carbonic acid, separated by means of a filter press, and the pure sugar juices thus obtained boiled for the separation of the sugar as described above. Another method consists in removing the salts which prevent the crystallization of the sugar by the process of osmosis. A third method consists in the use of strontium or barium hydroxid for the separation instead of lime salts, as in the Steffen process; or, finally, the molasses may be subjected to fermentation and distillation and the sugar therein contained thus converted into alcohol.

The above is the general method used for the manufacture of raw sugar. If refined sugar is to be made, the juices and sirups are passed over bone black to decolorize them and the crystals are washed in the centrifugal in order to make them perfectly white. The small, hard, colorless crystals thus obtained when dried in a revolving drum form the granulated sugars of commerce. Another method consists in treating the juices with sulphurous acid and purifying the crystals by washing them with sirup of varying degrees of consistency until all the molasses adhering thereto is washed away.

HOME MANUFACTURE OF SUGAR.

The question is often asked if beet sugar can not be made in a small way so that farmers could club together, put up a cheap apparatus, and produce their own sugar. On account of the elaborateness of the process and the costly nature of the machinery which is necessary to produce beet sugar even in a small way, it is not believed that it could be profitably made in the way indicated. A small factory could not possibly compete with a large one, and hence there is no encouragement to be offered in the way of producing homemade beet sugar. The Department has no knowledge of any successful beet-sugar factory of this kind. There is no country producing any notable quantity of beet

sugar in which home apparatus costing only a few thousand dollars have any appreciable influence on the output of sugar. Russia has been cited as an exception to this rule. The output of beet sugar in Russia annually is about 750,000 tons. The total number of factories in operation is about 300. The average annual output of each factory in round numbers is 5,000,000 pounds, representing an average consumption of 25,000 tons of beets. From these figures it is seen that the average size of the Russian beet-sugar factory is not greatly different from that of other European countries.

WASTE PRODUCTS.

The waste products of the factory consist of the pulps and molasses. The molasses is used for various purposes, either for making sugar, as described above, for fertilizing purposes, for the manufacture of alcohol, or sometimes for cattle food. The pulps make a valuable cattle food. They may be fed in the fresh state or preserved in silos. Lately extensive experiments have been made in drying the pulps and preserving them in the dried state, and these experiments have been fairly successful. It is stated that the value of the pulps for feeding purposes is from one-fourth to one-fifth of the value of the beets.

COST OF MANUFACTURE.

The cost of manufacture depends on as many factors as that of beet growing. Chief among these are transportation, fuel, weather, and labor. Perhaps the most important of these factors is the price of fuel. In some localities coal can be had for $1.25 per ton; in others the cost may reach as high as $10 per ton.

The manufacture of beet sugar is conducted without governmental supervision in this country, and any exact account of its cost is inaccessible. To show what it may be, with large experience and the highest skill and management, the mean cost of manufacture in 113 German factories is given:

Mean capital invested in each factory		$193,400.00
Total receipts for sugar, molasses, and pulps per ton of beets		11.10
Mean cost of beets per ton of 2,204.62 pounds	$4.90	
Salaries per ton of beets	.26	
Labor per ton of beets	.73	
Interest on investment per ton of beets	.36	
Coal per ton of beets	.63	
Miscellaneous expenses per ton of beets	.96	
Total expense of manufacture per ton		7.84
Profit per ton of beets		3.26

The mean net profit for each factory was $34,240. The price paid for beets, however, is in most cases fictitious, the beet growers owning the

factory and preferring to share in the general profits rather than to charge a high price for the beets. First-class beets rarely sell for less than $5 per ton. The Western Beet Sugar Company, of Watsonville, Cal., stated that in its first campaign, 1888–89, the cost of manufacture amounted to $80.80 per ton of sugar. At the present time it appears that with the best machinery and most economical processes beet sugar can be made in this country at a cost of from 3 to 4 cents per pound when the price of rich beets does not exceed $5 a ton.

COST OF FACTORY.

The cost of building a first-class beet-sugar factory is much greater than is commonly supposed. From the most reliable data at hand it may be stated that in Europe the cost of erecting a factory with the most modern machinery, of a capacity of at least 300 tons of beets per day, is about $200,000. In this country it is probable that, owing to the increased cost of transportation and the higher price of labor, the cost of a similar factory would be at least $250,000. As has been intimated before, it is not advisable to attempt to manufacture beet sugar with smaller factories or with machinery and appliances which do not represent the latest improvements. It is true that there are many parts of a sugar factory which have not changed much within the last twenty years, but even the multiple-effect apparatus, the strike pans, and the centrifugals, which represent the most stable parts of the machinery, have undergone considerable changes within the time mentioned. Probably one of the greatest dangers which the beet-growing industry in this country will meet is the tendency to begin the erection of a beet-sugar factory with cheap, old, or worn-out apparatus and appliances and without a proper technical study of all the questions involved. The avoidance of this danger is all the more difficult, because there are few engineers in this country who have devoted themselves to the study of this problem, and European experts are not likely to understand and comprehend American methods and measures. Numerous inquiries have been received at this office for directions for making beet sugar with such appliances as a cider mill and sorghum-molasses evaporator might afford. It would not be right to encourage the attempt to manufacture beet sugar in any such way. Nor should the expectation be excited among our farmers that they will be able to make a crude article of sugar which they can dispose of to a central factory for refining purposes. It is best to recognize at the very first the great expense which attends the erection of a sugar factory and the necessity for its meeting every modern requirement. Beet growing and beet-sugar manufacture are two distinct industries, but with common aims and interests.

COOPERATIVE FACTORIES.

It is seen from the foregoing paragraph that the farmer can have no reasonable hope of successfully establishing a home beet-sugar factory. It is not just, however, that he should be deprived of any cooperation in the process of manufacture or a reasonable share of the profits arising therefrom. The methods which have been practiced in Europe for securing these results are probably those which will eventually come into use in this country. The cooperative sugar factory, in which the farmers growing the beets hold a part or the majority of the stock, realizes the desired end. The growers of beets holding shares in the factory have a greater interest in its prosperity, try to grow better crops, and to secure in every way a higher yield. The cooperative factory renders impossible those disagreements between capital and agriculture which do so much to retard the progress of the industry and to embitter the feeling of the farmer against the factory. To show the extent of the participation of shareholders in factories in the growing of beets in Germany, it may be stated that of the 11,672,816 metric tons of beets delivered to the German factories in 1895–96, 2,689,004 tons were grown by shareholders. Inasmuch as the farmers in a beet-sugar community are uniformly prosperous, they are able to subscribe for shares in a factory, and by a community of interests practically control its operations. The industry of growing beets is not yet sufficiently advanced in the United States to render possible any definite outline of the best plan of securing cooperation between the farmer and the capitalist. At the outset, it would probably be impossible to secure among the farmers alone a sufficient amount of capital to properly equip a factory. Even could this be done, the additional difficulty would be encountered of a lack of experience among the shareholders, leading to poor judgment in regard to the methods of conducting the manufacturing operations. As long as the proprietors of the factory and the farmers growing the beets are satisfied with the contracts which they make, there is no urgent necessity of the establishment of cooperative enterprises. When the number of beet-sugar factories in this country, however, begins to reach the hundreds, favorable opportunities of cooperative establishments will be presented.

STATISTICAL.

Unit of value.

In the data giving the production and consumption of sugar the unit of value commonly employed is the ton. By reason of the fact that the ton in this country expresses a unit of varying magnitude a considerable degree of confusion is often introduced into statistical tables. In the following data, when not otherwise expressed, the term ton is used as the representative of 2,240 pounds. The short ton, namely, 2,000 pounds, is a more convenient unit of expression, but is not used

by Willett & Gray, the publishers of sugar statistical data in this country. The metric ton, which is used on the continent of Europe, is a weight of 1,000 kilograms, equivalent to 2,204.62 pounds.

In the tables which follow some slight differences will be noted in data relating to the same subject. These differences arise from the impossibility of securing exact statements relating to statistical data. Not having at hand the means of revising the statistical tables, it has been thought best to give the figures of the best authorities without attempting to harmonize them.

Production of beet sugar in the United States from 1830 to 1899.

The following table, showing the production of beet sugar in the United States from 1830 to the present time, is taken from the Weekly Statistical Sugar Trade Journal for January 7, 1897, and January 5, 1899:

Production by years from 1830 to 1899.

1830	A few hundred pounds	1885	600 tons
1831–1837	None	1886	800 tons
1838–1839	1,300 pounds	1887	255 tons
1839–1862	None	1888	1,010 tons
1863–1871	300 to 500 tons per annum	1889	2,600 tons
1872	500 tons	1890	2,800 tons
1873	700 tons	1891	5,359 tons
1874–1877	Under 100 tons per annum	1892	12,091 tons
1878	200 tons	1893	20,453 tons
1879	1,200 tons	1894	20,443 tons
1880	500 tons	1895	30,000 tons
1881–1882	Less than 500 tons	1896	40,000 tons
1883	535 tons	1897–1898	41,347 tons
1884	953 tons	1898–1899	33,960 tons

Location of beet-sugar factories in the United States.

The following beet-sugar factories are now (February, 1899) in operation:

The Western Beet Sugar Company, Watsonville, Cal.; The Chino Valley Beet Sugar Company, Chino Valley, Cal.; The Alameda Sugar Company, Alvarado, Cal.; The Norfolk Beet Sugar Company, Norfolk, Nebr.; The Oxnard Beet Sugar Company, Grand Island, Nebr.; The Pecos Valley Beet Sugar Company, Eddy, N. Mex.; The Utah Sugar Company, Lehi, Utah; The Binghamton Beet Sugar Company, Binghamton, N. Y.; First New York Beet Sugar Company, Rome, N. Y.; Ogden Sugar Company, Ogden, Utah; Oregon Sugar Company, La Grande, Oreg.; Michigan Sugar Company, Bay City, Mich.; The Los Alamitos Sugar Company, Los Alamitos, Cal.; The California Beet Sugar and Refining Company, Crockett, Cal.; The Minnesota Sugar Company, St. Louis Park, Minn.; The Wisconsin Beet Sugar Company (in liquidation), Menominee Falls, Wis.

Factories are building or nearly completed at the following places:

Spreckels (Salinas), Cal. (Spreckels Sugar Company); Oxnard (Hueneme), Cal. (Pacific Beet Sugar Company); Santa Maria, Cal. (Union Sugar Company); Grand Junction, Colo. (Colorado Sugar Manufacturing Company); Pekin, Ill.

New factories are proposed at the following places:

Detroit, Mich. (Detroit Sugar Company); Peoria, Ill. (Illinois Sugar Company); Benton Harbor, Mich. (Wolverine Sugar Company); Monroe, Rochester, Caro, West Bay City, Alma, Grand Haven, Port Huron, Marine City, and Kalamazoo, Mich.; Lyons and Dunkirk, N. Y.; Springville, Utah; Newcastle, Pa.

There are also rumors of plants to be built at Irving, N. Y.; Toledo and Sandusky, Ohio; Corunna, Alpena, Mt. Clemens, and Tawas City, Mich.; Hamlet, Ind.; Omaha, Nebr.; Sioux Falls, S. Dak.; Fresno, Cal.

World's sugar crop.

The total sugar crops of the world for the past four years are given in the Weekly Statistical Sugar Trade Journal for January 19, 1899, as follows:

World's sugar crop.[1]

	1898-99.	1897-98.	1896-97.	1895-96.
United States (beets, 33,960, 1898-99; 41,347, 1897-98; 40,000, 1896-97; 30,000, 1895-96)	*Tons.* 268,960	*Tons.* 351,794	*Tons.* 322,009	*Tons.* 267,720
Porto Rico	70,000	54,000	54,000	50,000
Canada (beets)	300	300	300	500
Cuba, crop	450,000	314,009	219,500	240,000
British West Indies:				
Trinidad, exports	50,000	53,000	53,000	58,000
Barbados, exports	47,000	53,500	58,249	47,800
Jamaica	27,000	30,000	30,000	30,000
Antigua and St. Kitts	22,000	25,000	29,000	24,000
French West Indies:				
Martinique, exports	32,000	35,000	35,000	35,000
Guadeloupe	40,000	45,000	45,000	45,000
Danish West Indies—St. Croix	12,000	13,000	13,058	8,000
Haiti and Santo Domingo	48,000	48,000	48,800	50,000
Lesser Antilles, not named above	8,000	8,000	8,000	8,000
Mexico, exports	2,000	2,000	2,000	2,000
Central America:				
Guatemala, crop	9,000	9,000	8,000	7,000
San Salvador, crop	4,000	4,000	3,000	2,000
Nicaragua, crop	1,500	1,500	500	500
Costa Rica, crop	500	500	200	200
South America:				
British Guiana (Demerara), exports	100,000	100,000	99,789	105,000
Dutch Guiana (Surinam), crop	6,000	6,000	6,000	6,000
Venezuela				
Peru, crop	75,000	70,000	70,000	68,000
Argentine Republic, crop	75,000	110,000	165,000	130,000
Brazil, crop	165,000	195,000	210,000	225,000
Total in America	1,513,260	1,528,603	1,480,405	1,409,720
Asia:				
British India, exports	50,000	50,000	50,000	50,000
Siam, crop	7,000	7,000	7,000	7,000
Java, exports	635,000	541,581	473,420	605,025
Japan (consumption 195,000 tons, mostly imported)				
Philippine Islands, exports	140,000	165,000	197,000	240,000
Cochin China	31,000	30,000	30,000	30,000
Total in Asia	863,000	793,581	757,420	932,025
Australia and Polynesia:				
Queensland	65,000	65,000	70,000	60,000
New South Wales	30,000	30,000	30,000	30,000
Hawaiian Islands	240,000	204,833	224,220	201,632
Fiji Islands, exports	30,000	30,000	30,000	30,000
Total in Australia and Polynesia	365,000	329,833	354,220	321,632
Africa:				
Egypt, crop	105,000	85,000	100,000	92,000
Mauritius and other British possessions	150,000	120,000	150,000	140,000
Reunion and other French possessions	45,000	45,000	48,000	44,700
Total in Africa	300,000	250,000	298,000	276,700
Europe—Spain	8,000	8,000	8,000	8,000
Total cane-sugar production	3,049,260	2,910,017	2,898,045	2,948,077
Total beet-sugar production (Licht)	4,790,000	4,825,529	4,916,586	4,285,429
Grand total cane and beet sugar production	7,839,260	7,735,546	7,814,631	7,233,506
Estimated increase in the world's production	103,714			

[1] In the above table is comprised the entire sugar production of all the countries of the world, including those crops which have heretofore been ignored in statistics. These figures include local consumptions of home production wherever known.

Production of beet sugar in Europe for four years, 1895 to 1899.

The quantities of sugar produced in Europe for four years, from 1895 to 1899, the last crop partially estimated, collated by Licht in his monthly circular and published in the Weekly Statistical Sugar Trade Journal of February 2, 1899, are as follows:

European sugar crop for four years, 1895 to 1899.

	1898-99.	1897-98.	1896-97.	1895-96.
	Tons.	*Tons.*	*Tons.*	*Tons.*
Germany	1,710,000	1,852,857	1,836,536	1,615,111
Austria	1,040,000	831,667	934,007	791,405
France	830,000	821,235	752,081	667,853
Russia	750,000	738,715	728,067	712,096
Belgium	220,000	265,397	288,009	235,795
Holland	150,000	125,658	174,206	106,829
Other countries	155,000	190,000	202,990	156,340
Total	4,855,000	4,825,529	4,916,496	4,285,429

Number of factories, yield of beets per acre, and yield of sugar in the principal beet-sugar countries of Europe.

Germany.—Number of factories in operation during 1895-96, 397; quantity of beets used, 11,672,816 tons; hectares cultivated, 376,669 (acres, 930,372); mean yield per hectare, 31,000 kilos (pounds per acre, 27,669); mean price of beets per metric ton, 17.70 marks (equal to $4.64 per ton of 2,000 pounds); yield of raw sugar (92 per cent) on weight of beets 13.11 per cent; average output of sugar per factory, 4,068 metric tons.

France.—Number of factories in operation during 1895-96, 356; quantity of beets used, 5,411,484 metric tons; yield of refined sugar on weight of beets, 10.97 per cent; hectares under cultivation, 204,715 (405,852 acres); yield of beets in metric tons per acre, nearly 10.5; average output of sugar per factory, 1,876 tons.

Austria-Hungary.—Number of factories in operation in 1895-96, 216; quantity of beets used, 5,760,000 metric tons; yield of raw sugar (92 per cent) on weight of beets, 13.5 per cent; average output of sugar for each factory, 3,663 tons.

Russia.—Number of factories in operation during 1895-96, 277; quantity of beets used, 5,311,888 metric tons; per cent of sugar in beets, 15.71; average output of sugar for each factory, 2,828 tons.

Consumption of sugar in the United States.

The first of the following tables shows the consumption of sugar in the United States for each of the years 1896, 1897, and 1898, with a detailed statement of the origin of the sugar consumed, and the second is a statement of the consumption in the United States from 1881 to 1898, inclusive. The tables are taken from the Weekly Statistical Sugar Trade Journal of January 5, 1899.

Consumption of sugar in the United States during the years 1896, 1897, and 1898.

Source of sugar supply.	1898.	1897.	1896.
	Tons.	*Tons.*	*Tons.*
Meltings of the four ports	1,502,000	1,597,000	1,508,000
Of which were domestic from Louisiana crop	6,443	9,662	1,411
Meltings of foreign sugar through New Orleans	1,495,557	1,587,338	1,506,589
Foreign refined through Galveston	9,431	59,793	30,520
	23	1,060	2,000
Total	1,505,011	1,648,191	1,539,109
Export of raw sugar from Atlantic ports	1,450	14,955	11,500
Export of refined sugar from Atlantic ports	4,192	2,516	3,100
Total exports to be deducted	5,642	17,471	14,600
Consumption of foreign sugar through Atlantic ports	1,499,369	1,630,720	1,524,509
Consumption of foreign sugar through San Francisco	139,668	129,887	146,454
Total consumption of foreign sugar	1,639,037	1,760,607	1,670,963
Louisiana crop consumed during the year	310,447	282,009	237,720
Texas crop consumed during the year	7,000	7,000	5,500
Total consumption of domestic cane sugar	317,447	289,009	243,220
California beet-sugar crop	16,700	32,417	27,300
Nebraska beet-sugar crop	4,700	6,460	8,000
Utah beet-sugar crop	5,700	1,570	4,700
Oregon beet-sugar crop	660	.....	.....
New Mexico beet-sugar crop	1,000	525	.....
Minnesota beet-sugar crop	1,100	.....	.....
Michigan beet-sugar crop	2,500	.....	.....
New York beet-sugar crop	1,600	375	.....
Consumption of domestic beet sugar	33,960	41,347	40,000
Consumption of sorghum sugar	300	300	300
Consumption of maple sugar	5,000	5,000	5,000
Molasses sugar made in United States from foreign molasses	1,700	150	603
	1,997,444	2,096,413	1,960,086
Add undistributed refined brought over from previous year	75,000	50,000	30,000
	2,072,444	2,146,413	1,990,086
Deduct undistributed refined carried over to next year	25,000	75,000	50,000
Total consumption of all sugar	2,047,444	2,071,413	1,940,086

Consumption per capita is 61.1 pounds in 1898, 63.7 pounds in 1897, 60.9 pounds in 1896, 64.23 pounds in 1895, 66.64 pounds in 1894, 63.83 pounds in 1893, 63.76 pounds in 1892, 67.46 pounds in 1891, 54.56 pounds in 1890, 52.64 pounds in 1889, 54.23 pounds in 1888, 53.11 pounds in 1887, 52.55 pounds in 1886, 49.95 pounds in 1885, and 51 pounds in 1884.

Consumption of sugar in the United States during the years 1881 to 1898, inclusive.

Year.	Total consumption of United States.	Increase(+) or decrease(—).	Year.	Total consumption of United States.	Increase(+) or decrease(—).
	Tons.	*Per cent.*		*Tons.*	*Per cent.*
1898	2,047,444	— 1.16	1889	1,439,701	— 1.21
1897	2,071,413	+ 6.90	1888	1,457,264	+ 4.62
1896	1,940,086	+ 0.53	1887	1,392,909	+ 2.73
1895	1,949,744	— 3.27	1886	1,355,809	+ 8.11
1894	2,012,714	+ 5.08	1885	1,254,116	+ 0.14
1893	1,905,862	+ 2.83	1884	1,252,366	+ 7.0
1892	1,853,370	— 1.102	1883	1,170,375	+10.3
1891	1,872,400	+22.96	1882	1,061,220	+ 6.8
1890	1,522,731	+ 5.80	1881	993,532	.....

Increase for seventeen years, 106.07 per cent, or 6.24 per cent per annum.

Consumption of sugar per head.

The following table, taken from the Weekly Statistical Sugar Trade Journal, shows the consumption of sugar in pounds per head for all the countries of Europe and for the United States for four years from 1891–92 to 1894–95:

Consumption of sugar for the United States and all the countries of Europe for 1891–92 to 1894–95.

Country.	Population 1895.	1894–95.	1893–94.	1892–93.	1891–92.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*
Germany	51,650,000	26.78	26.71	22.90	23.56
Austria	43,456,000	19.81	16.57	17.20	16.05
France	38,800,000	30.61	27.80	27.86	30.46
Russia	100,239,000	10.94	11.06	10.94	10.34
Holland	4,732,000	31.30	25.55	22.90	26.88
Belgium	6,325,000	22.50	21.73	21.09	21.29
Denmark	2,300,000	45.41	42.96	43.53	43.63
Sweden and Norway	6,873,000	24.95	24.82	23.64	24.14
Italy	30,724,000	6.65	7.07	7.00	7.18
Roumania	5,800,000	4.03	4.07	4.53	3.90
Spain	17,650,000	13.68	12.47	12.38	11.06
Portugal and Madeira	5,082,000	12.92	13.09	12.51	12.43
England	38,927,000	86.09	84.78	77.40	80.73
Bulgaria	3,310,000	8.88	7.14	6.07	5.16
Greece	2,235,000	6.26	7.29	7.38	8.62
Servia	2,256,000	4.01	4.25	4.22	3.81
Turkey	21,983,000	7.65	7.25	7.64	9.30
Switzerland	2,895,000	44.66	42.30	31.62	31.30
Europe	385,177,000	25.64	23.25	22.02	22.64
United States	69,753,000	62.60	66.64	63.83	63.76
Total	454,930,000	31.07	29.33	28.20	29.00

Rate of increase in consumption.

The rate of increase in the consumption of sugar for twenty-three years for the principal sugar-consuming countries is as follows:[1]

Rate of increase in the consumption of sugar in five principal countries.

Country.	Per cent in 23 years.	Per cent a year.
France	142	6.18
Germany	159	6.91
Austria	107	4.65
England	90	3.50
United States	278	12.10

[1] Zeit. des Vereins f. Rubenzuckerind., June 1896, S. 248.

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FARMERS' BULLETINS.

These bulletins are sent free of charge to any address upon application to the Secretary of Agriculture, Washington, D. C. Only the following are available for distribution:

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No. 16. Leguminous Plants for Green Manuring and for Feeding. Pp. 24.
No. 18. Forage Plants for the South. Pp. 30.
No. 19. Important Insecticides: Directions for Their Preparation and Use. Pp. 20.
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No. 88. Alkali Lands. Pp. 23.
No. 89. Cowpeas. (In press.)

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 52.

Rev.ed.
follows

THE SUGAR BEET:

CULTURE, SEED DEVELOPMENT, MANUFACTURE, AND STATISTICS.

BY

H. W. WILEY,

Chief of the Bureau of Chemistry, and formerly Director of the Department Sugar Beet Experiment Station in Nebraska.

[Second Revised Edition, September, 1901.]

By G. L. SPENCER.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1901.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY,
Washington, D. C., September 24, 1901.

SIR: I have the honor to transmit herewith the manuscript of the second revised edition of Farmers' Bulletin No. 52.

The subject-matter of this bulletin remains practically the same as in the original edition. It was found necessary to revise the statistical part, however, and to bring it up to date. This has been done in an admirable manner by Dr. G. L. Spencer, the sugar expert of this Bureau, and special agent of the Twelfth Census for the collection of statistics relative to the sugar industry in the United States.

It is hoped that in its new form this bulletin may prove as beneficial as its predecessors in directing the interest which is being manifested in the culture of the sugar beet and in the manufacture of sugar therefrom into reliable channels of experiment and investigation. The continued demand for the information is sufficient justification for its republication.

Respectfully,
H. W. WILEY, *Chemist.*

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE SUGAR BEET.

INTRODUCTION.

Among the farmers of the country there is in general an erroneous opinion respecting the manufacture of beet sugar, especially concerning the cost of a factory. It is well that our farmers should cherish no illusions in regard to this matter. The manufacture of beet sugar is an industry entirely distinct from agriculture, and can only be successfully accomplished by the investment of large capital under the direction of skilled artisans. From the nature of the process it is quite improbable that any simple method of home manufacture of beet sugar will ever prove commercially successful. The juices of the beet are extracted with difficulty. They contain large quantities of mineral salts, which render the crude sugar and molasses made therefrom bitter and unpalatable. Simple processes for the extraction of the juice can at best remove only from 60 to 70 per cent of the sugar which the beet contains, and thus a percentage of loss is incurred which at the very outset renders it impossible for a home apparatus to compete with a large factory. Beet sugar, for the reasons given above, can not be used in the raw state, as is the case with the products derived from the sugar cane, sorghum, and the maple tree. The refining of the sugar is a process which requires an expensive outlay for machinery and a high degree of supervisory skill. It can not therefore be accomplished upon the farm. The various schemes which have been proposed whereby the farmer is assured of the possibility of preparing a crude product to be subsequently shipped to a central refinery are not practicable on account of the radical difficulties above outlined. The low prices at which sugar is sold render imperative in the process of manufacture the most economical methods, which are only made possible by the use of improved machinery operated under the direction of technical experts. The farmers of this country, as is the case with those of Europe, in respect of the beet-sugar industry, must be satisfied with acquiring the requisite degree of agricultural skill to produce a crop of beets with a paying tonnage and a high content of sugar.

One of the remarkable facts shown by the statistical tables in this bulletin is found in the information they contain showing that the sugar beet has been able on demand to supply the remarkable deficiency in the world's sugar crop produced by the Cuban war. In three years the

supply of sugar furnished by that island fell from 1,000,000 to about 100,000 tons, and yet there was no appreciable deficit noticed in the total sugar production of the world.

The remarkable opportunities for the extension of profitable agricultural industries in this country, through the medium of the sugar beet, should not be suffered to pass unimproved, and the farmers of our country should not rest satisfied until they see our own fields produce the sugar which we consume.

CLIMATIC CONDITIONS.

Experience has shown that the sugar beet reaches its highest development in north temperate latitudes. So far as the production of beets with high tonnage is concerned, it is found that this can be accomplished far to the south, but beets grown in such localities are, upon the whole, less rich in sugar and less suitable for the manufacture of sugar than those grown farther north. It must be remembered, however, that the expressions north and south do not refer to any absolute parallels of latitude, but rather to isothermal lines, which in many cases run obliquely to the parallels of latitude and in some cases cross them almost at right angles. As a result of many years of careful experimentation, it may be said that as far as temperature alone is concerned the sugar beet attains its greatest perfection in a zone of varying width through the center of which passes the isothermal line of 70° F. for the months of June, July, and August. This zone for this country is shown in the accompanying map (fig. 1).

THE THEORETICAL BEET-SUGAR BELT OF THE UNITED STATES.

This isothermal line, for the United States, begins near the city of New York and passes up the Hudson River to Albany; thence turning westward, it runs near Syracuse and passes in a southwesterly direction, touching the shore of Lake Erie near Sandusky, Ohio; turning thence in a northwesterly direction, it enters Michigan and reaches its highest point in that State near Lansing; then going in a southwesterly direction, it enters the State of Indiana near South Bend, passes through Michigan City, then in a northwesterly course continues through the cities of Chicago and Madison, reaching its highest point near St. Paul, Minn.; thence it extends in a southwesterly direction until it enters the State of South Dakota, where it turns again northwest and reaches its highest point in Dakota just above the forty-fifth parallel of latitude, where it crosses the Missouri River. The isothermal line then turns almost due south, following very closely the one hundred and first degree of longitude until it leaves the State of Nebraska near the northeast corner of Colorado; passing in a southwesterly direction through Colorado, it reaches, at Pueblo, almost to the one hundred and fifth degree of west longitude, whence it passes in a slightly southeasterly direction into New Mexico, turns to the

west, and crosses the one hundred and fifth degree of longitude at about the thirty-second degree of latitude. Then turning westward,

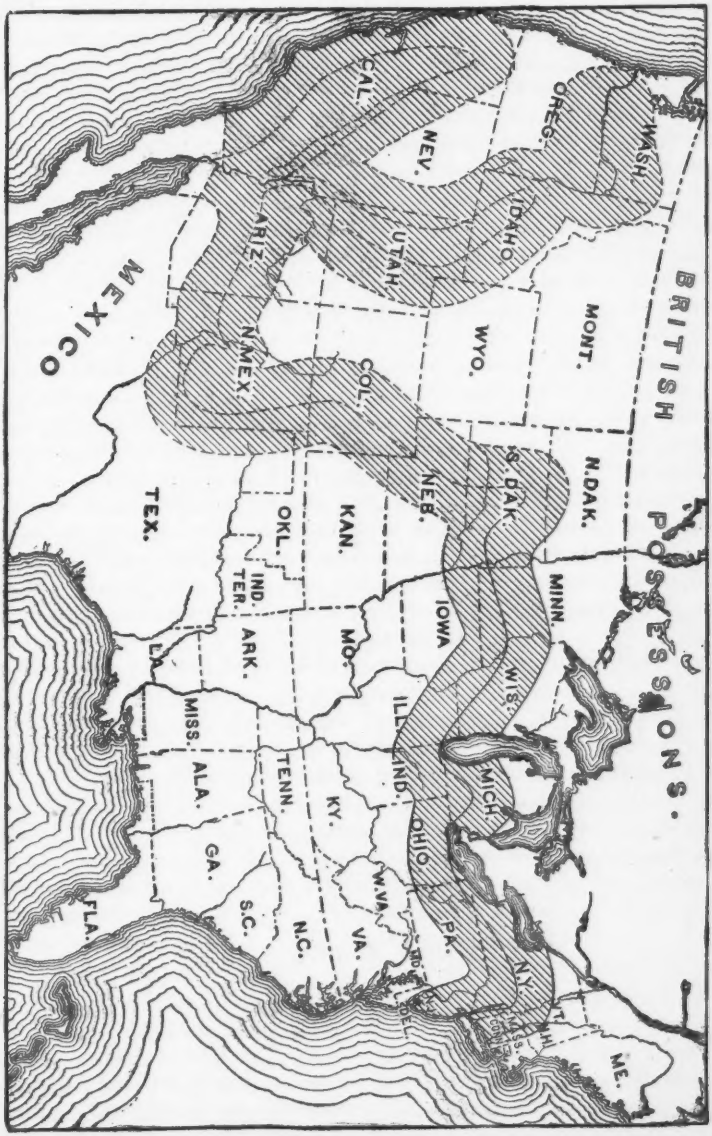

FIG. 1.—Map showing temperature zone in which the sugar beet attains its greatest perfection.

it passes in a very irregular line through the States of California, Oregon, and Washington.

Extending a distance of 100 miles on each side of this isothermal line is a belt which, for the present, may be regarded as the theoretical beet-sugar area of the United States. There are doubtless many localities lying outside of this belt, both north and south, in which the sugar beet will be found to thrive; but this will be due to some exceptional qualities of the climate or soil and not to any favorable influence of a higher or lower temperature. A mean temperature of 70° F. in the summer, however, must not be regarded as the only element of temperature which is to be taken into consideration. In those localities where the winters come early and are of unusual severity will be found greater difficulties in the production of sugar from the sugar beet than in those localities where the winters are light and mild, although the mean summer temperature of both localities may be represented by 70° F. As an illustration of this difficulty may be cited northern Nebraska and South Dakota, where the winters are of great severity, and southern California, where there is scarcely any winter at all.

The mean summer temperature of these localities is about the same, but the continuation of a semisummer temperature through the winter in southern California greatly favors the growth of the beets and the manufacture of the sugar. In many of the northern States the beets, which are to be worked during the winter time, have to be protected by silos. A cold climate is favorable to the storage of beets during the manufacturing season. In southern California and other places similarly situated the beets can be protected without any covering, or at most with only a slight covering of leaves or straw. The season for planting in a mild climate is also longer. For instance, in southern California planting can commence as early as January and continue till June, thus giving a beet crop coming continuously into maturity from the 1st of August to the 1st of December. In other localities the planting must be accomplished in a short time, say from the 10th of May till the 1st of June. Before the first of these dates the ground will be too cold for planting, and after the second the season will be so late as to prevent the maturity of the beets before frost. When the field is properly plowed and subsoiled in the late autumn the farmer will be able to take advantage of the first favorable opportunity in the spring to prepare the surface of the soil and plant the seed.

CONDITIONS OF PRECIPITATION.

Although conditions of temperature must be taken into consideration in selecting sites for beet-sugar factories, those of rainfall must also be studied. The sugar beet requires a certain amount of moisture in order to produce its normal crop. This moisture must be derived either from precipitation in the usual way, by irrigation, or else the soil must be of that particular quality which will allow subterranean moisture to reach the rootlets of the plants. Soil of this latter kind appears to exist in many localities in California, where beets are grown almost without

rain. The porous and sandy soils adjacent to many of the Western rivers, such as the Platte River in Nebraska and the Arkansas River in Kansas, also appear to furnish a sufficient amount of subterranean moisture to produce a good crop in connection with the rainfall, of which, however, but little is expected in those localities during the summer months. Where there is little subterranean moisture, and where irrigation is not practicable, the endeavor should be made to secure localities for the growth of the sugar beet where an average summer precipitation of from 2 to 4 inches per month may be expected. There are many conditions of agriculture, however, under which the beet becomes quite independent of extremes of precipitation. The beet may thrive with very little rainfall or with a great deal, if properly cultivated in a suitable soil.

GROWTH OF BEETS ON IRRIGATED LANDS.

The experience of more than ten years in California has shown that the climatic data, regarded as of prime importance in beet culture in Europe, can not be regarded as rigidly applicable to this country. The successful growth of sugar beets in the arid regions of our country, with and without irrigation, has introduced a new factor into the science of beet meteorology. While the arid area on which beets can be grown without irrigation is probably confined almost exclusively to the coast valleys of California, the successful commercial production of sugar beets in Utah has opened up a new and extensive field for the extension of the sugar industry over large areas suited to irrigation in the Western and Southwestern regions of the United States. It is certain now that Colorado and Utah may become great sugar-producing States, and it is probable that other areas in the arid region may become equally productive. California has already set the pace of progress, and the other arid States will not be slow to follow. The high cost of good irrigation renders it imperative that the areas under culture be devoted to a crop which is capable of producing a more valuable yield than is afforded by cereal culture. Of all the home markets for our domestic agricultural products, there is none so insistent or so expansive as that for sugar. With an annual consumption of 2,220,000 tons, and with a certainty of rapid increase, the demand for sugar promises to be the salvation of American agriculture.

The northern parts of our Eastern and Middle States and the States of Oregon and Washington have at least an equal chance for the successful production of beet sugar with the fields of Germany and France. The irrigable parts of the great Southwest, it is believed, have advantages of soil and climate which will enable them to enter into competition in the production of beet sugar. To be able to control the moisture in the soil is a matter of prime importance to the beet grower. In the arid region the beet can be left to mature at the proper time by withholding the water. Subsequently there is no

danger of loss due to second growth, so easily induced by late warm autumnal rains.

In a dry soil the beet can endure without damage a low temperature, which would prove quite disastrous in a wet climate. More complete maturity may be thus obtained, and a more leisurely harvest. In fact, there is no staple crop which can compete with the sugar beet in demanding the favorable attention of those interested in irrigation. If a net profit of from $10 to $20 per acre can be secured, from $100 to $200 per acre can be paid for the land. It is estimated that nearly 100,000,000 acres of land in the arid regions of the United States may eventually be irrigated, being nearly one-fifth of the total area. Of this area perhaps 10 per cent is capable of easy and speedy irrigation. One million acres planted to beets would yield, under intensive culture, a quantity of sugar sufficient, with the Louisiana product, for domestic consumption. There is nowhere in sight a more promising prospect for agricultural development than in the production of sugar beets on irrigated lands.

FIG. 2.—White Improved Vilmorin sugar beet.

VARIETIES OF BEETS.

All kinds of sugar beets are botanically identical with the common garden beet (*Beta vulgaris*). The differences in varieties have arisen by reason of special selection and culture, producing a pure strain of some valuable peculiarity in the beet. These accidental valuable qualities, by careful selection, have become fixed, and are associated with certain external properties which have thus come to be regarded as distinguishing characteristics.

The shape and size of the beet, its color, the character of the foliage, whether erect or spreading, etc., are the most frequent marks of distinction. The beets are also frequently designated by the names of those who have developed them, by the name of the town or locality in which they have been grown, or by their color.

Among the more frequently occurring varieties grown in Europe may be mentioned the Vilmorin Improved, Kleinwanzlebener, Improved Kleinwanzlebener, White Excelsior, White Imperial, Simon Le Grande, Florimond and Bulteau Desprez Richest, Imperial Demesmay, French Very Rich, La Plus Riche, etc.

The two varieties which have been most widely grown in this country are the Vilmorin Improved and the Kleinwanzlebener. Certain varieties, such as the Vilmorin and Kleinwanzlebener types, give a large yield of sugar from a comparatively small tonnage of beets, and others yield both a large tonnage and a large amount of sugar. Sugar manufacturers prefer those varieties which yield a high percentage of sugar, since the juices are purer and the expenses of manufacture and the cost of the raw material are less. Large beets yielding a large tonnage were usually grown in Europe prior to the adoption of legislation placing a tax on the beet itself instead of on the sugar, and were preferred on account of the value of the pulp for cattle feeding.

FIG. 3.—Kleinwanzlebener sugar beet.

The certainty that the seed has been grown according to the most scientific methods is of great importance to the beet grower and sugar manufacturer, since the one may depend upon producing rich beets and receive fair compensation for his labor and the other is enabled to operate his factory economically. The beet has reached such a high state of perfection as to make the least degree of laxity in its treatment exceedingly dangerous to its qualities.

The general type of the Vilmorin Improved is illustrated by fig. 2. This beet is the result of thirty-five years of methodic and persevering selection based upon the lines to be indicated hereafter. In regard to its preservation, it is recognized that it holds its sugar content better than any other variety. In those factories in which sugar is manufactured from the Improved Vilmorin in connection with other

varieties, it is the custom to reserve this variety for the end of the season and to work up the less reliable beets at an earlier date. It is also said to resist better than any other variety the unfavorable influence of certain characters of soil and of certain manures. In black soils, rich in organic matter, it gives great industrial results, while most other varieties of beets become watery or saline in excess. Excessive quantities of nitrogenous fertilizers, which are carefully excluded from ordinary varieties, can be applied with safety to the Improved Vilmorin, as a great number of experiments have shown that this can be done without serious deterioration in the quality of the beet and with a considerable increase in weight. From thousands of analyses it has been established that the percentage of sugar which can be obtained with this variety is about 16. Its average yield under favorable conditions can be stated to be from 12 to 16 tons per acre.

FIG. 4.—Brabant sugar beet.

Perhaps more important for general cultivation than the Vilmorin variety is the beet known as the Kleinwanzlebener, which at the present time has probably a wider cultivation than any other sugar beet. The general character of this beet is shown by fig. 3.

This beet has a conical root, straight and even, quite large at the head and rapidly tapering. It is distinguished from the Improved Vilmorin by its brighter color and its lighter-colored leaves, which

are beautifully undulating or scalloped about the edges. Coming from a cross in which the Improved Vilmorin entered largely, the Kleinwanzlebener is to-day a fixed variety and is equally well produced in France and Germany. It succeeds in soil of an alluvial nature and average richness and on level plateaus. In soils very rich in humus it ripens poorly and loses much of its richness. Like the Improved Vilmorin, toward the end of vegetation its leaves are completely spread. In those conditions of culture where the Improved Vilmorin gives from 12 to 16 tons per acre, the Kleinwanzlebener gives from 14 to 18 tons. It is, however, generally inferior to the Improved Vilmorin in saccharin richness, which the whiter and more watery appearance of its flesh would make known at first view. Nevertheless, from 13 to 15 per cent of sugar can be obtained in the beet in field culture.

FIG. 5.—White French Rich sugar beet.

The Brabant sugar beet is altogether different in aspect from the preceding varieties. It is long, rising well above the level of the soil, and carries a foliage vigorous in growth and upright in position. This variety would seem at first view to have come from the white varieties used for forage; nevertheless, its great vigor, its abundant production, and its sufficiently high content of sugar make it a beet quite valuable in those countries where the tax is placed upon the amount of sugar made rather than upon the beet. The Brabant

sugar beet will give easily 20 tons per acre, and may be made to contain 12 per cent of sugar. Its general appearance is shown by fig. 4.

In France the adoption of legislation placing the tax upon the beet itself has not entirely banished the Brabant variety, but it has succeeded in transforming it into one of greater richness in sugar. This variation of the Brabant beet has been called the French Rich sugar beet, and seems destined to have a brilliant future, preserving in its general aspect, and notably in its foliage, many of the characteristics of the Brabant. The French Rich sugar beet differs distinctly from the Brabant in the fact that it grows entirely under the soil, is more slender, and has a ruddier skin and more compact flesh. Its yield is superior to the Vilmorin Improved and equal to the Kleinwanzlebener. The content of sugar of this new variety is rarely inferior to 14 per cent. Its general appearance is shown by fig. 5.

The Imperial sugar beet is one which is largely grown throughout Europe. It has a regular conical outline, with oval-shaped top, and its leaves have rather short stems. There are different varieties, such as the Old Imperial, Improved White Imperial, and the Improved Rose Imperial. Other varieties of beets largely grown are the Electoral, the Improved Elite, the Improved Imperial Elite, the Imperator, the Olive-Shaped, the Excelsior, etc.

Following are the names of some of the firms producing high-grade beet seed of the above named and other varieties in Europe:

Vilmorin, Andrieux & Co., Paris.
Dippe Bros., Quedlinburg, Germany.
Carl Schobbert & Co., Quedlinburg, Germany.
Desprez, père et fils, Cappelle, par Templeuve (Nord) France.
G. Schreiber & Son, Nordhausen, Germany.
Klein & Soukoffsky, à Bielany, Poste Beresovka, Podolien, Russia.
S. L. Ziemann, Quedlinburg, Germany.
Otto Breustedt, Schladen-am-Harz, Germany.
F. Demesmay, Cysoing (Nord), France.
Schlitte & Co., Aumühle bei Gorsbach, Germany.
H. Hornung & Co., Frankenhausen, Germany.
Heinrich Mette, Quedlinburg, Germany.
C. A. F. Degering, Quedlinburg, Germany.
Ladislaus Mayzel, Brzozówka, Post Stopnica, Russian Poland.
Martin Grashoff, Quedlinburg, Germany.
Adolph Strandes, Rittergut Zehringen bei Cöthen (Anhalt), Germany.
Association Maurus Deutsch, 8 Rue Lafitte, Paris.
M. Knauer, Gröbers, Saxony, Germany.

In this country considerable quantities of beet seed have been grown by the Utah Sugar Company, Lehi, Utah, chiefly for its own consumption. It is probable that there are other growers of beet seed in this country, but no definite information concerning that point can be given.

SOIL.

The sugar beet does not require a particular kind of soil for its proper production. In general, soils are described for practical purposes as clayey, sandy, loamy, or alluvial soils; all of these soils will produce beets. The black prairie soils also have been found, with proper cultivation, to produce excellent beets. Perhaps the best soil may be described as a sandy loam; a soil containing a happy equilibrium between organic matters, clay, and sand.

In general it may be said that any soil which will produce a good crop of Indian corn, wheat, or potatoes will, under proper cultivation, produce a good crop of sugar beets. The soil on which sugar beets are grown, however, should be reasonably level, and this being the case, it should be well drained. Natural drainage on level soil being somewhat deficient, it is advantageous that tile drainage be practiced. It would be difficult to grow sugar beets on level land without good drainage, especially in a rainy season.

FERTILIZATION.

Happily, in most American soils there is still sufficient natural fertility to produce a good crop of sugar beets; whereas in the soils of Europe, where sugar beets have been grown for years, the farmers must depend on fertilizers to insure a remunerative crop.

Two kinds of fertilizers are employed—stall manure from the farm and artificial manure, generally known as commercial fertilizers. For general purposes stall manure is desirable. It should be applied, in a well-rotted condition, in the autumn before the ground is plowed. The quantity per acre depends, of course, on the fertility of the soil; but in any case it is not best to apply a very heavy dressing. In poor soils it is best to apply the fertilizer for several years in succession, rather than to apply enough at once to bring it up to the required state of fertility. Too copious an application of stall manure is apt to produce overgrowth in the beets, which makes them ill suited to the manufacture of sugar. If the fertilizer be applied in an unrotted condition, it is apt to seriously injure the crop in case of dry weather.

Of commercial fertilizers three classes are employed containing, respectively, nitrogen, phosphoric acid, and potash. In some instances these three elements are found combined in the same commercial fertilizer. Nitrogenous manure should be applied with great care to sugar beets. It tends to produce a very heavy growth of the beet and thus to diminish its content of sugar. Potash and phosphoric acid can be applied with great freedom to beet fields; in general they act much better in conjunction than when applied separately.

The principles of fertilization depend upon the fact that a soil of good quality should have returned to it all that the harvest has removed, and a poor soil be supplied with those elements in which it is deficient.

Nothing can be more certain than that a soil to which this restoration is not fully made will gradually lose its faculty to produce plants in normal quantity and composition. Culture experiments with artificial liquid manures have not been carried so far with the beet as with some other plants, and therefore the dependence between the composition of such liquids and the evolution of the beet has not yet been determined. The basis is also wanting whereon the direct working of the manure on the beet can be predicted; and here is met the well-known difficulty of getting the manures into those layers of the soil from which the beet chiefly draws its supplies of mineral plant foods.

PRECAUTIONS IN APPLYING STABLE MANURE.

Since experience has taught that beets raised on fields freshly fertilized with stable manure are inferior for purposes of manufacture, the rule has long been established that not the beets, but the previous crop should be fertilized with this material, or that the beets should be raised in rotation as the second or even third crop. Unfortunately this rule, so important to the factories, is not always observed, and as a consequence of heavy manuring large crops have been produced, but at the cost of diminished sugar content and lessened price. This rule applies especially to stable manure and night soil, as well as to Chile saltpeter, the misuse of which has produced such serious consequences for factories, but not to phosphatic manures, which usually exert a favorable influence upon the crop. Experiments conducted at the New York Station, at Geneva, have shown that the judicious use of well-rotted stable manure has proved beneficial in the growth of beets both in yield per acre and in sugar content.

QUANTITIES OF PLANT FOOD REMOVED FROM THE SOIL.

The constituents to be taken into account in the necessary restitution to the soil of the elements removed by beets are potash, phosphoric acid, magnesia, and nitrogen. Following are the quantities of these constituents in 1,000 pounds of beets and beet leaves, determined by numerous analyses:

Principal constituents of sugar beets.

Constituents.	Roots.	Leaves.
	Pounds.	*Pounds.*
Potash	3.3	6.5
Phosphoric acid	0.8	1.3
Magnesia	0.5	3.0
Nitrogen	1.6	3.9
Total ash	7.1	18.1

It will be seen from the relation between the roots and leaves that for equal weights the amounts abstracted by the latter are considerably

greater and deserve especial consideration in case the leaves are used for cattle food. From this point of view the leaves should be left in the field. It is certain that otherwise complete restitution is attended with some difficulty. The form in which the above-mentioned plant constituents shall be returned to the soil is well established for phosphoric acid and magnesia, and partly for nitrogen. Superphosphates, with greater or less content of phosphoric acid or with addition of a nitrogenous element, and basic phosphatic slags are of universal application. As has been shown by direct investigations, the magnesia may be nearly all returned in the filter-press cakes from the factory, though a more uniform distribution than is thus secured is much to be desired.

The soil ingredients most essential for the successful production of sugar beets are nitrogen, phosphoric acid, potash, lime, and magnesia.

Most soils contain a sufficient quantity of magnesia, and the press cakes from the factory, which should be returned to the soils, will supply any deficiency. The same is true in regard to lime, although there are some soils in which the supply of lime is naturally deficient. Such soils would be benefited by an application of land plaster, burned lime, phosphatic slags, or ground shells. Phosphoric acid and potash are supplied in the form of ordinary commercial fertilizers—the phosphorus as ground bone, superphosphate, and basic slag, and the potash as kainite or other salt. Of the various potash compounds found in natural deposits, all are useful. Preference is due only to compounds with organic substances. Consequently the molasses, or its residue after distillation, and the liquors of the molasses-working processes, all rich in potash, are themselves very valuable materials for potash fertilization, and should be carefully preserved for such use. It must not be supposed, however, that the demand for potash will be satisfied by returning to the soil the molasses from the crop of beets in the form of waste products. Aside from the leaves, for which if taken from the field a largely increased potash return must be made, the molasses itself does not represent the entire amount of potash taken. Factories which produce raw sugar sell with it also potash, and in all factories the waste waters carry away potash compounds sufficient to account for the difference between the amount of potash in the beets and in the molasses.

Phosphoric acid is best supplied in the form of ground bone, superphosphate, or basic slag from steel factories.

Nitrogen may be supplied in the form in which it exists in ground bone, or from the refuse of the slaughterhouses in the form of dried blood and tankage, or as cotton-seed meal or oil cake, or as nitrate of soda, sulphate of ammonia, etc. The simultaneous application of stall manure and nitrate of soda is not advisable because of the possible loss of nitrogen due to the development of denitrifying ferments.

As to the relation which the quantity of material returned to the soil should bear to the quantity abstracted by the beet, it may be said

in general that it is desirable to return as much nitrogen, from one and a quarter to one and a half times as much potash, and two and a half times as much phosphoric acid as have been removed by the roots. Greater additions of potash and phosphoric acid have no disadvantageous effects upon the crop. Direct investigations in regard to the relation between the sugar and potash in consecutive crops for many years have failed to give the least ground for a contrary conclusion. But it must not be expected, on the other hand, that increasing fertilization, especially potash fertilization, will produce proportionately increasing crops, as has been asserted by some.

EFFECT OF NITROGENOUS MANURES ON QUALITY OF BEET.

The opinion has generally prevailed among beet growers during late years that heavy nitrogenous manuring, especially with nitrate of soda, produces no injurious effect on the quality of the beet. This opinion was based on the fact that in such beets the sugar per cent was only slightly diminished. Nevertheless the quality of a beet may be impaired even with little or no diminution of the sugar content by reason of the increase of the percentage of nonsugars present.

In this respect it has been shown that heavy manuring with nitrogenous substances greatly injures the quality of the beet for sugar-

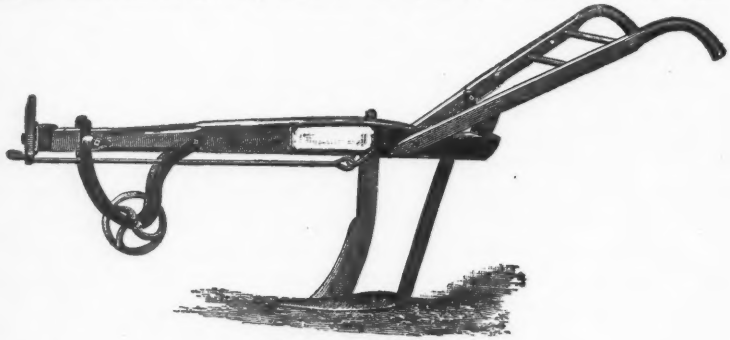

FIG. 6.—Subsoil plow.

making purposes. The apparent coefficient of purity of the juice is also frequently misleading, since no account is taken of the nature of the nonsugars present.

The real purity of the beet is also to be distinguished from the apparent purity of the juice. The real purity of the beet is obtained by dividing the percentage of sugar in the beet by the total solid matter in solution therein; the apparent purity of the juice by dividing the percentage of sugar therein by the apparent percentage of solids as indicated by the specific gravity. Judicious fertilizing with nitrate of soda, however, is beneficial, and this form of nitrogenous fertilizer is in many respects the best known for beets.

ROTATION.

Beets do best after wheat or some other cereal. It is true that soils on which beets have not been grown, as the soils of this country, may produce beets for several years without harm. Nevertheless, proper rotation is always desirable.

A good scheme of rotation is, first, wheat; then beets; then clover, one crop of which is cut for hay and the second crop plowed under; then potatoes, wheat, and beets in the order mentioned. By this method, and a judicious use of stall manure and commercial fertilizers, the fertility of the soil can be maintained and even increased. Beets should follow wheat or other cereal crop, because this crop, being harvested early, leaves the ground ready for late autumn plowing, a prerequisite to successful beet culture.

FIG. 7.—Cultivator.

PREPARATION OF THE LAND FOR PLANTING.

The field in which beets are to be planted should be selected and plowed in the late autumn to the depth of at least 9 inches. The plow in each furrow should be followed by a subsoiler, which will loosen the soil to the depth of 6 or 7 inches more. A convenient subsoil plow is shown in fig. 6. Each field to be planted in beets should thus have the soil prepared by thoroughly loosening it to the depth of from 15 to 18 inches. The land, being exposed through the winter, becomes quite mellowed, and in the spring can be prepared for planting by a

simple treatment of the surface. This is done after plowing by a thorough surface cultivation until the surface of the soil is reduced to perfect tilth. The large cultivator shown in fig. 7 can be conveniently

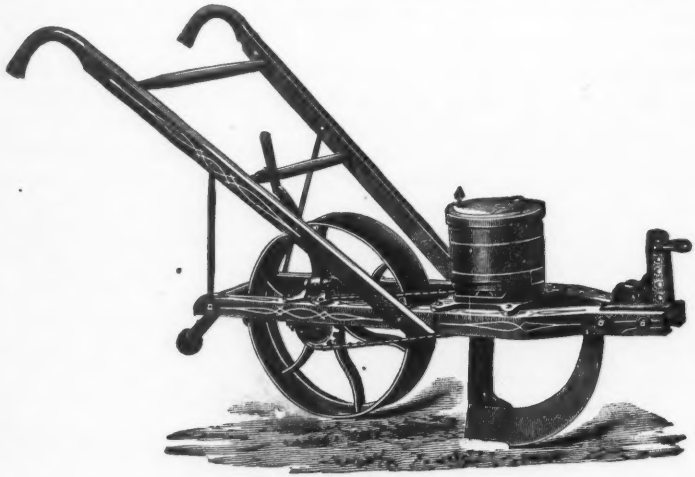

FIG. 8.—Seed drill.

used for this purpose, followed when necessary by a harrow and roller. It is desirable, however, that each portion of the field to be planted should be thoroughly prepared immediately before the planting takes

FIG. 9.—Seed drill.

place. For instance, if the planting is to be made on a given day, the soil should be thoroughly prepared on the previous day. Thus all weeds and grasses which have started to grow are killed, and the beets have an even chance with the weeds for growth. If, on the

other hand, the soil be prepared a week or even a few days before planting, the weeds and grasses get a good start, and it is difficult to free the beets therefrom.

PLANTING.

The beets may be planted either by hand or by drill. Hand planting may be practiced when a very small plat is to be put in beets, but where a field embracing several acres is to be planted it is not convenient. In such cases planting by drill is best. Almost any garden drill can be adapted to use with beet seed. Special drills for sugar-beet seed are made by many manufacturers of agricultural implements. One is shown in fig. 8. The form of drill represented in fig. 9 may also be used. In planting by drill it is necessary to use from 15

FIG. 10.—Hand seed drill.

to 20 pounds of seed per acre; in planting by hand from 10 to 15 pounds will be found sufficient.

Another very convenient hand drill, which is especially fitted with a beet seed dropping apparatus, is shown in fig. 10. This machine marks and excavates the row, drops the seed at any required distance, and covers it.

The beets should be covered to the depth of from one-half to 1½ inches, according to the state of the soil. If the soil be moist and in excellent condition, the beet seed should not be covered more than half an inch. If, on the other hand, the soil be very dry and early rains are not probable, the seed should be covered to the depth of 1½ inches.

In large cultures it is often important to be able to plant more than one row of beets at a time. For this purpose the planter shown in the

accompanying figure (11) is convenient. The machine is adapted to planting four rows at a time. The runners can be adjusted at any distance from 16 to 20 inches apart, and the quantity of seed planted can by varied from 15 to 25 pounds to the acre.

In planting by hand or by drills an effort should be made to distribute the seeds singly and at equal distances apart.

TIME OF PLANTING.

Beets should be planted as early in the spring as possible. Experience has shown that the early-planted beets almost uniformly produce a larger yield and with a higher content of sugar than the late-planted. No exact date can be fixed which would be suitable to all localities. In most of the localities in the beet area of the United States it will not

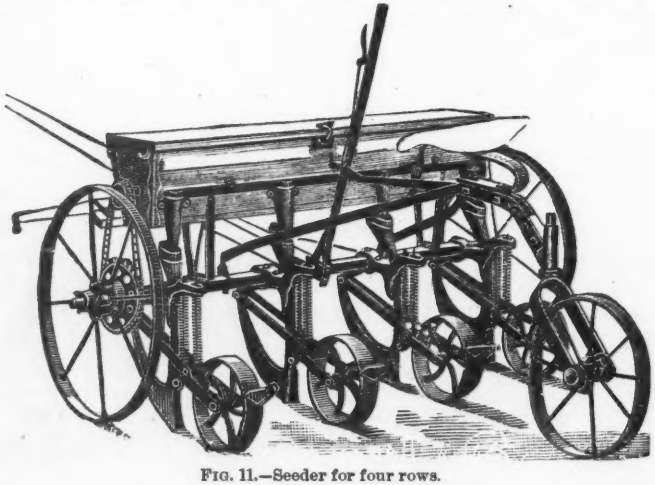

FIG. 11.—Seeder for four rows.

be found practicable to plant earlier than the first week in May. In exceptional seasons a part of the sowing may be accomplished in April.

On the Pacific coast, especially in central and southern California, the sowing can take place at a much earlier date. At Chino planting has been practiced in December with favorable results. In 1895 one acre of beets planted in the autumn yielded at the rate of 12½ tons per acre, with an average sugar content of 15.2 per cent and a purity of 81.5. In the same field 8 acres planted in the spring yielded only 5 tons per acre, with an average sugar content of 14.7 and a purity of 80.5. It was observed, however, that the autumn-planted beets had a higher content of marc than those planted in the spring. Under date of January 4, 1897, the agricultural manager of the Chino Beet Sugar Factory wrote that he had planted 5 acres of beets on the 21st of December and that they were then well out of the ground.

He further stated it to be the intention of the company to continue the experiments of autumnal and winter planting on a more extensive scale, and to plant from 50 to 100 acres in the autumn of 1897 for the harvest of 1898. In this connection it must be remembered that the climatic conditions of the Chino Valley are almost unique for beet-sugar production, and the experience there obtained would not be applicable to beet-sugar regions in general.

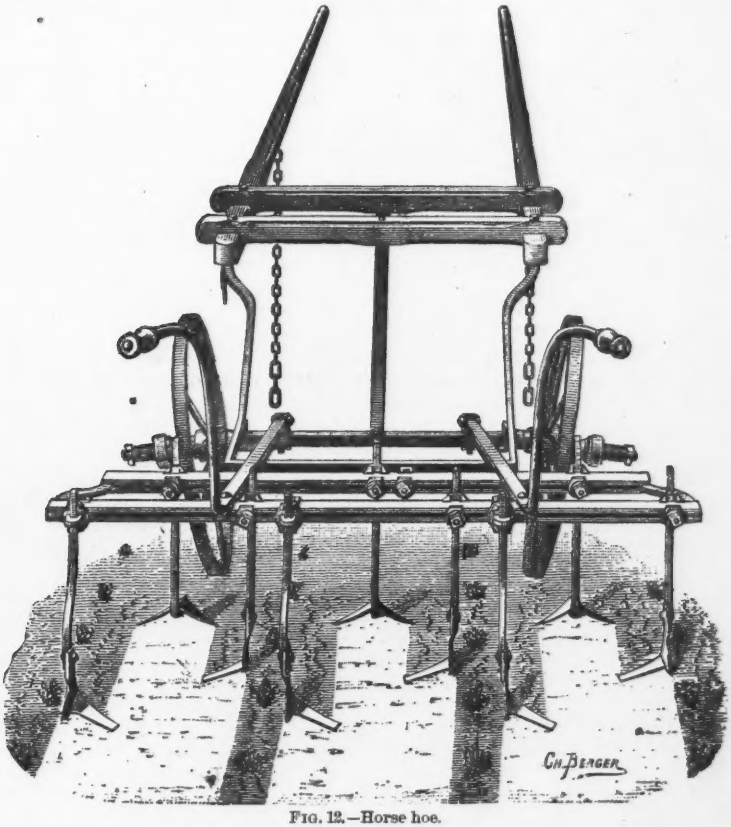

FIG. 12.—Horse hoe.

CULTIVATION.

As soon as the beets are large enough to mark the rows, cultivation with the horse or hand hoe may be commenced. Cultivation must not be postponed, except for unfit condition of the soil, if the grass and weeds appear above the ground at the same time with the beets.

When large fields are cultivated, the horse hoe, a model of which is shown in fig. 12, may be used. For smaller fields a similar apparatus drawn by hand may be employed. Convenient instruments of this

kind are shown in figs. 13 and 14. This plow frees the spaces between the rows of beets from weeds and the guard prevents the growing beets from being covered by the loose soil.

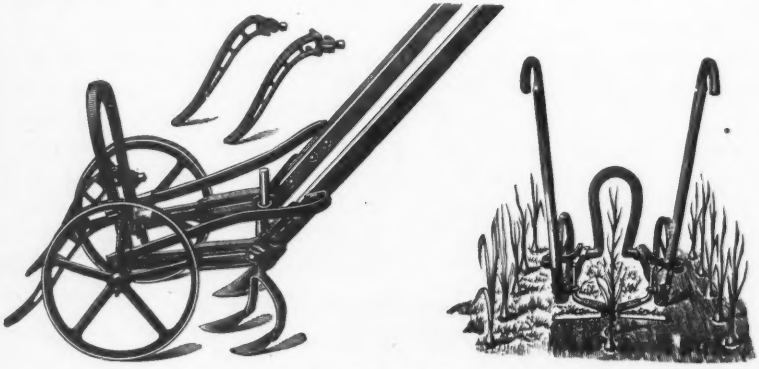

FIG. 13.—Hand hoes.

When the beets show four leaves the process of thinning should take place. If the rows be 18 inches apart a vigorous plant should be left every 8 or 10 inches. Careful selection should be made and all

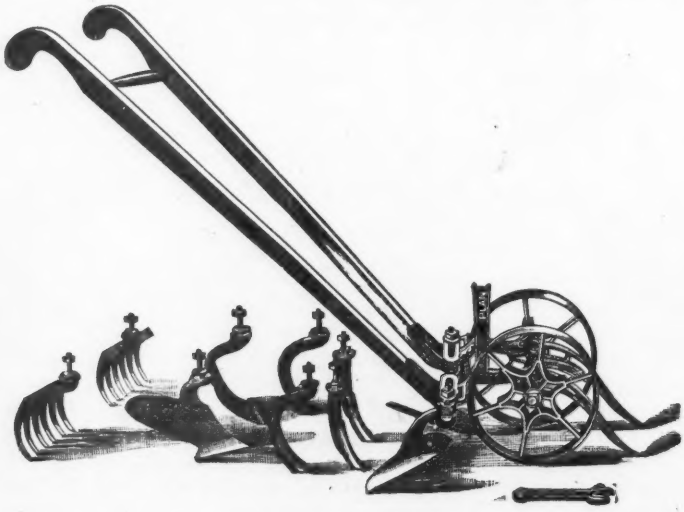

FIG. 14.—Cultivator for beets.

the puny plants destroyed. It is better to save the vigorous plants even if regular intervals are not preserved, but no space should be left greater than from 12 to 15 inches in extent. Much of the thin-

ning work can be done with a narrow hoe, but where the plants are very close together, at the place where the preserved plant is to grow, the work must be done by hand. It is well to give a thorough hand

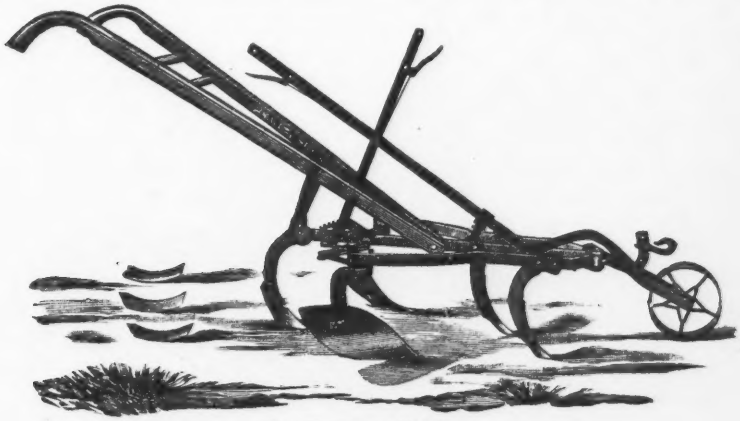

FIG. 15.—Deep cultivator.

hoeing at the time of thinning, and the subsequent cultivation, in most seasons, may be carried on with horse power.

When the beets are more advanced a few deeper cultivations may be

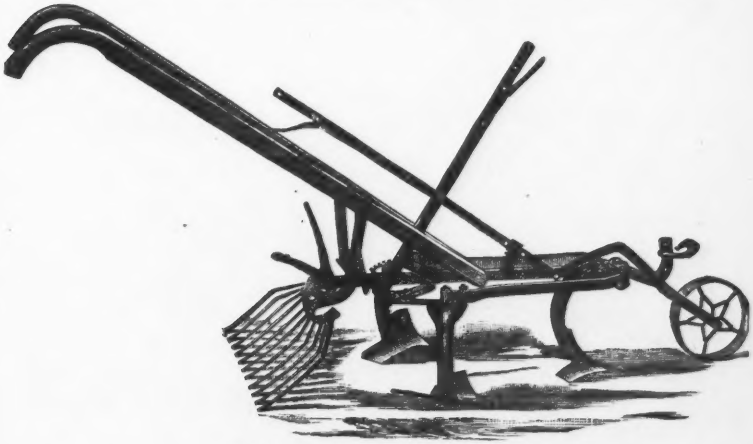

FIG. 16.—Plow cultivator with harrow.

desirable, and for these any good narrow cultivator may be used for single rows or wider ones for double rows. The instruments shown in figs. 15 and 16 will be found suitable to this kind of work.

The cultivation in all cases should be conducted for the double

purpose of keeping the beets entirely free of weeds and for preserving the proper tilth of the surface of the soil. It may be said that at least once a week during the period of growing, lasting from six to eight

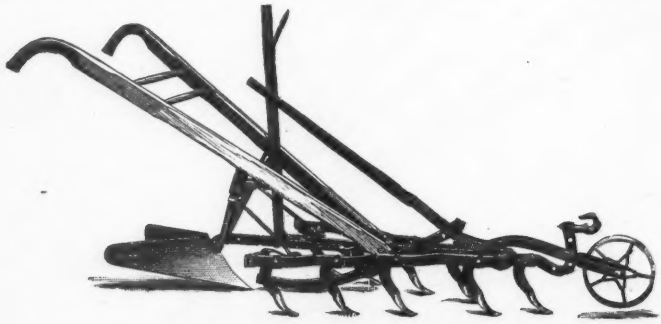

FIG. 17.—Beet cultivator for irrigated lands.

weeks, the beet field should be cultivated. If the season be very dry, more frequent cultivation will be found useful. The final cultivation should leave the soil practically level. During cultivation care should be taken not to injure either the leaves or the root of the beet, and

FIG. 18.—Cultivator for four rows.

when the foliage of the growing crop begins to well cover the surface of the soil cultivation may be suspended.

In growing beets with irrigation a cultivator which will prepare the furrow for conducting the water over the field is important. Such a

machine is shown in fig. 17. In this instrument the plow shown in the rear of the cultivator teeth forms the required furrow and can be set at any required depth. In ordinary cultivation the brush harrow shown in fig. 16 can be inserted in place of the plow.

In the cultivation of large areas an implement adapted to four rows of beets is desirable. Such an implement, however, can not be advantageously used, except in those cases where the beets have been sown with an implement of similar capacity. The cultivator shown in fig. 18 is suitable for use on fields which have been planted with the seeder shown in fig. 11. The gangs of plows in this instrument are easily handled by a spring lift, and by reason of a peculiarity of

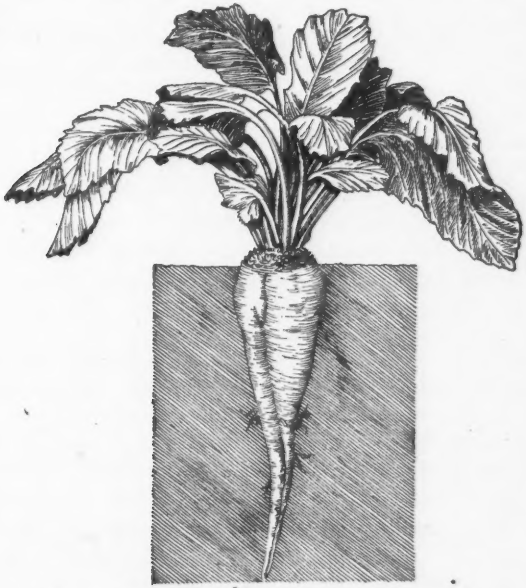

FIG. 19.—Correct position of a mature beet in the soil.

construction run steadily and adapt themselves exactly to the rows, so that the operator needs only to watch a single row. Different kinds of implements for cultivation can be easily attached so that the instrument can be used as a plow, a cultivator, or a harrow.

POSITION OF THE BEET IN THE SOIL.

It is important not only that a sugar beet should be of a proper size and shape, but also that it be grown in such a manner as to secure the protection of the soil for all of its parts except the neck and foliage. The proper position for a beet to occupy in the soil at the end of growth is shown in fig. 19. This position can only be secured for the beet by

growing it in a soil sufficiently pervious to permit of the penetration of the taproot to a great depth. It is for this reason that subsoiling in the preparation of a field for the growth of sugar beets is of such great importance. If the beet, in its growth, should meet a practically impervious subsoil at the depth of 8 or 10 inches, the taproot will be deflected from its natural course, lateral roots will be developed, the beet will become disfigured and distorted in shape, and the upper portion of it will be pushed out of the ground. Experience has shown that the content of sugar in those portions of a beet which are pushed above the soil is very greatly diminished.

COST OF GROWING BEETS.

The cost of growing an acre of beets depends on so many varying factors as to render it impossible to give an estimate which is reliable for every locality. The differences in rent of land, cost of labor, methods of culture, etc., require that any estimate which may be given should be revised for almost every series of conditions. The following estimate of the cost per acre is based on a yield of 12 tons per acre, except in Utah.

An assumed yield per acre is requisite in estimating the cost of harvesting, etc., since a part of the cultivation and the harvesting are often contracted at a certain price per ton of beets. The figures given below are from actual averages of the past few years or from estimates by experienced men.

It should be noted that in the Pacific coast and other Western States farm laborers are paid as high as $2 per day. The actual average paid by one California factory in 1899 to white, Chinese, and Japanese laborers was $1.829 per day. It should be stated that field labor in California was paid unusually high wages in 1899 on account of its scarcity.

Approximate cost of sugar-beet culture.

Items.	California.	Utah.	Nebraska.	Illinois.	Michigan.
Clearing the land			$1.00 to $1.50	$0.70 to $1.25	$2.25
Plowing and harrowing	$5.37	$3.50	2.50 to 3.00	2.00 to 2.45	
Seed and seeding	1.80	2.75	3.25 to 3.85	3.30 to 3.40	2.50
Bunching and thinning	14.40	4.00	7.00	4.50 to 5.00	7.00
Hoeing		4.00	2.00 to 4.00	6.00 to 7.00	4.00
Cultivating		2.00	1.50 to 1.60	1.75 to 2.25	1.50
Other expenses		[1]1.50		2.00 to 3.00	
Harvesting and delivering	[2]1.50	[2]15.00	11.00 to 13.20	7.00 to 7.50	17.20
Total	23.07	32.75	28.25 to 34.15	27.25 to 31.85	34.45
Cost of siloing when necessary			2.50 to 8.00		

[1] Cost of irrigation. [2] Exclusive of delivery. [3] Based on a yield of 15 tons per acre.

In the above estimate has been included the cost of the best culture, but nothing for rent of land or a reasonable application of fertilizers. It is probable that the actual cost to our farmers for the first few years of the beet industry will not exceed $25 to $35 per acre and in

many instances will fall below these figures. The price paid for the beets is dependent on many local considerations, but chiefly on the selling price of sugar and the richness of the beet.

It is reasonably certain, accidents of season aside, that a net profit of from $8 to $15 per acre may be expected from the proper culture of the sugar beet in localities near a factory when all the conditions of the best methods of culture are fulfilled.

In contrast with the above estimate, the actual figures submitted by Mr. J. Thomssen, of Hall County, Nebr., in a letter published in the Prairie Farmer, on the 3d of January, 1891, are given. The cost is given for a field of 5 acres, and the items are as follows:

Fall plowing, at $1 per acre	$5.00
Plowing in spring, at $1.25	6.25
Rolling twice, once before and once after planting	1.50
Planting by hand, at 75 cents per acre	3.75
Cultivating with hoe, at 75 cents	3.75
Thinning, at $10	50.00
Hoeing by hand three times and weeding necessary at time of hoeing	90.00
Cultivating by horse twice, at 75 cents	7.50
Running over with hoe to clear from remaining weeds	3.75
Total	171.50

Dividing this by 5 gives a total of $34.30 per acre.

As will be seen from the above, Mr. Thomssen makes no allowance for the rent of the land, used no fertilizers, and gives no estimate of the price of seed and of the expense of harvesting and hauling to the factory. But his field was hoed by hand three times, which with the proper implements is more than is necessary, one good hand hoeing being as a rule sufficient.

Mr. J. B. Henderson, of Alameda, Cal., reports the cost of growing and harvesting 10 acres of beets at $614.83, or $61.48 per acre. His farm is 1 mile from the factory. Mr. A. F. Richardson, of the same place, residing 2 miles from the factory, reports the cost of 11 acres at $535.04, or $48.64 per acre.

It is not wise to underestimate the actual cost of growing the beets, for this will lead the farmer to expect large profits which often in practice give way to actual deficits.

HARVESTING.

The time for harvesting varies in different localities. In southern California the beets planted in February are ready for harvesting in August. In general it may be said that beets planted the first week in May will be ready for harvesting about the 1st of October. Harvesting should be postponed to as late a date as possible, provided the beets are in no danger of a second growth and are not exposed to a freezing temperature. The leaves of the ripened beet change from a rich to a yellowish green, become drooping and applied closely to the

earth, and many of them die. The harvesting is easily accomplished by first loosening the beets in the soil and then removing them by hand. For loosening the beets the apparatus shown in fig. 20 may be employed. It can be used to advantage only when the rows are perfectly straight and the beets of a reasonably uniform size. The teeth of the apparatus are sunk deep enough into the earth to catch the beet below its middle part. In moving forward the plow catches the beets between its two prongs, which approach more nearly together in the rear, and on account of the angle at which the teeth are fixed the beets are lifted and the taproots broken. After the passage of the harvester the beets are easily lifted out of the ground by means of their leaves.

The next operation consists in removing the neck. This is done by

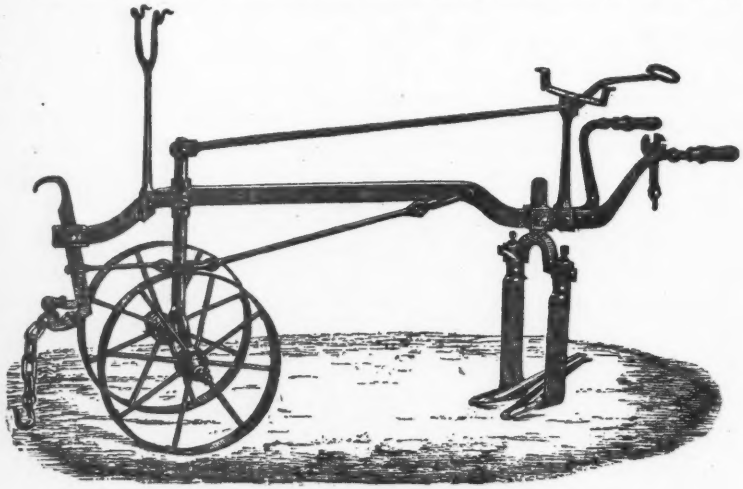

FIG. 20.—Beet harvester for one row.

a large knife and the top of the beet, called technically its neck, is cut off so as to remove, with the top, that portion of the beet to which the stems of the leaves have been attached.

The object of removing this portion of the beet is to prevent the mineral salts, which have accumulated in large quantities therein, from entering the factory. These mineral salts exercise a very deleterious influence on the crystallization of the sugar, and, therefore, should be removed. They are well fitted for feed or for fertilizing purposes and are of more value when left upon the soil than when removed to the factory. The neck is also much less rich in sugar than the other parts of the root.

The removal of the tops of the beets is a tedious process which, in Europe, is performed by women and children. In this country the process of topping the beets will prove much more expensive than in

Europe. It is probable that some mechanical device will be invented by which the beets can be topped, thus saving a large expense. So far as known at the present time, however, this process has not been successfully accomplished by machinery and the topping must still be done by hand. When the beets are topped they are thrown into piles, and the tops thrown over them as a protection from the sun or frost until they can be delivered to the factory.

The beets are best delivered to the factory in dump carts, which permit of their quick unloading. It is not customary for the farmers to silo their beets except in the simple manner indicated above.

SILOING.

When beets are to be preserved for manufacture during the winter months or for the production of seed, they must be carefully protected against frost. The simplest and the easiest method is to place them in piles and cover them with earth, not too deeply, for if they become too warm in the silo they rapidly lose in sugar content. When first siloed, say about the 1st of November, they should be covered with only a slight layer of earth; as the cold of winter becomes more intense this covering can be increased. In some localities only a slight covering of straw is necessary to protect the beets, as, for instance, in California. In other localities, such as in the Dakotas, Minnesota, and Wisconsin, it is probable that the beets would have to be covered to the depth of 2 feet, or even more, to protect them from frost.

Siloing is often done by the factory, as it would be very inconvenient to deliver beets from a distance to a factory in the middle of winter.

In most localities in the beet-sugar region of the United States it is probable that the harvesting and delivery to the factory could be entirely completed by the middle of November; although in some seasons there would be no danger whatever in leaving the roots in the earth until the 1st or even the 10th of December, while in California there is no danger at all of freezing.

In the construction of large silos due regard must be had for proper ventilation to avoid the danger of heating.

PRODUCTION OF SEED.

The production of seed is one of the most important operations connected with the sugar-beet industry. On the care and skill which are displayed in this process depend the improvement and maintenance of the sugar-producing qualities of the beet. There are many different methods employed for producing seed which will grow the richest sugar beets, but there will be mentioned here only a general outline of the principles which underlie the process. The beets which are to be preserved for seed are called "mothers" and are carefully siloed in the manner already indicated. They are selected at the time of harvesting

from specially grown beets or from fields of beets which have shown particularly good qualities on analysis. The size of the roots selected for mothers should be about the average for the best sugar beets, viz, from 20 to 24 ounces. Smaller beets than these might show a higher content of sugar, but it is not wise to produce a race of small beets by selecting the seed from the very smallest and richest beets grown. The weight of the mothers having been decided upon, the beets are next selected for their shape and external appearance. Those regular in shape and smooth in external form are to be preferred. Roots of irregular shape or with more than one taproot should be rejected.

The beets to be preserved for mothers are harvested with unusual care to avoid injury. The neck is not cut away, but the leaves are removed by cutting off the stems without injuring the neck of the beet.

The siloing should be of such a nature as to entirely protect the beets from frost and yet prevent their growth in the silo until the spring. The beets are removed from the silo at an early date in the spring and are immediately subjected to analysis for the final selection. In the early days of the beet industry the beets were selected almost solely on account of their specific gravity. A brine of a given strength was made, and the beets, thoroughly cleaned of dirt, were thrown into this brine. Those which would sink were selected as mothers, while those that would swim were rejected. At the present time the final selection depends upon the actual determination of the density of the juice of the beet which is to be selected as a mother and the estimation of its content of sugar. For this purpose a cylindrical piece of the beet is removed by an appropriate instrument cutting diagonally through the center of the root. This piece may weigh one-half ounce or even more, and its removal does not injure the beet for germinating purposes. The juice is expressed from this piece, and its specific gravity determined by weighing in it, at a given temperature, a silver button of known weight.

The sugar content of the juice is next determined by means of the polariscope. By means of these two data the qualities of the beet for the production of seed are determined and also the coefficient of purity; that is, the number obtained by dividing the percentage of sugar in the juice by the percentage of solid matters as determined by its specific gravity and multiplying the quotient by 100. In mother beets this number is found somewhere between 80 and 90. The actual method of selection may be illustrated as follows:

The operator determines beforehand his standard, which in most cases will consist of a juice containing from 16 to 18 per cent of sugar with a purity of 85. The beets are analyzed separately, and are at once divided into two great classes, namely, those in which either the content of sugar or the purity falls below the fixed figure, and, second, those in which these two numbers are equal to or exceed the fixed fig-

ures. It is sometimes customary to divide these two classes into two portions, viz, those roots in which the numbers are equal to or slightly above the standard, and, second, those which show exceptional richness. It is also customary to number each beet, and the number, which is cut into the skin of the beet, will remain legible even after the seed has ripened. Some of the producers of sugar-beet seed preserve the product of seed from each beet by itself, and do not use it to inaugurate the production of seed for commerce until it has received an additional year's trial.

Many seed producers determined the percentage of sugar in the weight of the beet by a direct analysis of a pulped sample and base the selection of the mothers on the number so obtained, without regard to the coefficient of purity.

By careful selection of mother beets, and scientific culture, the sugar beet has been raised to its present high standard of excellence, and is only maintained at this standard by constant supervision, such as has been indicated.

The sugar-beet seed produced by the above method is not sold for planting fields, but is used solely for the production of the seed of commerce in the fourth or sixth year from the parent, as the case may be.

DOMESTIC PRODUCTION OF BEET SEED.

The commercial production of beet seed of pure pedigree and high grade has not been practiced to any extent in this country. The Utah Sugar Company, and perhaps others, have grown seed for their own use. During the continuance of the experiment station at Schuyler, Nebr., a system for the production of beet seed of exceptionally high grade was inaugurated, embodying all the best features of the methods practiced in Europe. In the spring of 1893, 6,370 beets, which had been carefully selected on account of their physical characteristics and preserved in a silo over winter, were subjected to an analysis by removing a cylindrical core from each one and subjecting the expressed juice therefrom to a chemical examination. Allowing for the deterioration in sugar content which the beets had suffered during storage, the beets were classified by the analysis as follows:

Classification of beets.

Variety.	No. I grade (sucrose 18 per cent upward).	No. II grade (sucrose 15 to 18 per cent).	No. III grade (sucrose 12 to 15 per cent).
	Beets.	*Beets.*	*Beets.*
Original Kleinwanzlebener	36	465	448
Dippe's Kleinwanzlebener	6	483	1,176
Vilmorin Improved	8	600	734
Lemaire			476
Desprez			168
Elite Kleinwanzlebener	7	210	224
Total	57	1,758	3,276

The following statement gives the proportion of the beets analyzed which was eligible for propagation uses:

Number of beets of all grades accepted for seed production	5,091
Number of beets of all grades rejected for seed production	1,179
Total	6,270

By reason of the abolition of the experiment station the beet seed produced was sold to the highest bidder for a sum which would have brought for an acre under cultivation $172.60.

DEVELOPMENT FROM A SINGLE HIGH-GRADE BEET.

In the case of any given variety let it be assumed that a beet is found of good size and typical form, and exceptionally rich in its sugar content and the purity of its juice. The production of beets on a commercial scale from this single individual is accomplished as follows: The beet is preserved over winter and planted in the spring for the purpose of producing seeds. The seeds thus obtained are carefully freed from all imperfect and defective individuals, and planted the second year for the production of beets. Several hundred beets will likely be produced from this sowing. All of these beets which are of proper size and good form are preserved during the winter. In the third spring they are all carefully analyzed and those which reach or exceed a given standard are planted for the production of seed. It is probable that during this third season several thousand beets will be produced. All those which are of typical size and shape are preserved over the winter, and the fourth spring are planted without analysis, and the seed which they yield will be of sufficient quantity to be used in the fifth year for the production of sugar beets for the factory. It is seen by the above statement that at least five years are required for the production of seed for commercial purposes from any high-grade individual beet which may be selected for the purpose.

COMPARATIVE VALUE OF DOMESTIC AND FOREIGN SEED.

In the experiments conducted at the station at Schuyler during the season of 1893 a comparison of the beets grown from domestic and imported seeds was made. The plants from the native-grown seed seemed to have a higher vitality and to be better suited to the climatic conditions of the locality than those grown from imported seeds. They showed during the growing season a more abundant foliage and a better development of roots. This higher vitality and quality of the beets grown from domestic seed illustrate in a forcible degree the advisability of the production of our beet seed at home. Even granting that seeds produced in foreign countries have the same high qualities, it must be admitted that their vitality is in danger of being very much diminished during shipment to this country. The moist air of the holds of the ships in which they are transported often produces

moldiness and incipient germination, which tend to greatly diminish their value. Not only did the beets produced from the home-grown seed have a higher percentage of sugar, but they also afforded a higher yield per acre, as determined in the experiments at Schuyler. The mean tonnage per acre from the home-grown seed was 21.1 and from the imported seed 17.9. The mean pounds of sugar produced per acre from the home-grown seed was 5,891 and from the imported seed 5,185. This shows an increase of about 12 per cent in the actual quantity of sugar per acre when domestic seed was used. These data should be carefully studied by all those who are interested in the production of beet sugar in this country. Perhaps the time has not yet come for the inception of such a work, but it is evident that it will not be long before there will be a demand for the establishment in this country of a plantation or plantations devoted exclusively to the production of beet seeds on the most approved scientific principles.

The quantity of seed required to plant an acre is about 15 pounds. The approximate number of acres planted to beets in this country during the season of 1899 was 135,305, requiring 2,029,575 pounds of seed. More than 3,000,000 pounds of seed were required for the crop of 1901. It is evident that there is already an opportunity for the active operation of a large plantation devoted exclusively to the production of beet seeds for domestic use.

Another point to be considered is that by the importation of foreign seeds there is danger of introducing those diseases of beets which have occasioned such ravages in Europe.

MANUFACTURE OF SUGAR.

The process of making sugar from the sugar beet interests the agriculturist only from secondary considerations, and will be treated in the briefest possible manner to give an intelligent idea of its methods.

The beets are first conveyed to washing tanks provided with suitable apparatus for keeping them in motion and transferring them toward the end from which the fresh water enters, in order that the whole of the adhering soil, together with any sand and pebbles, may be completely removed. By a suitable elevator the beets are next taken to a point above the center of the diffusion battery, shown in fig. 21, whence they are dropped into a slicing apparatus, by which they are cut into pieces of greater or less length and of small thickness, and of such a shape that when placed in the cells of the battery they will not lie so closely together as to prevent the circulation of the diffusion liquors. When the cell is full of the sliced beets it is closed and the hot juices from the cell last filled are admitted and allowed to remain in contact with the cuttings for a few minutes. From 10 to 12 cells are thus kept in use. While one is filling another is emptying. The fresh hot water is always admitted to the cell next to be emptied and passes in succes-

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sion through all the cells under pressure, until it reaches the one last filled. From this cell a quantity of juice is drawn off each time and sent to the carbonatation tanks for purification.

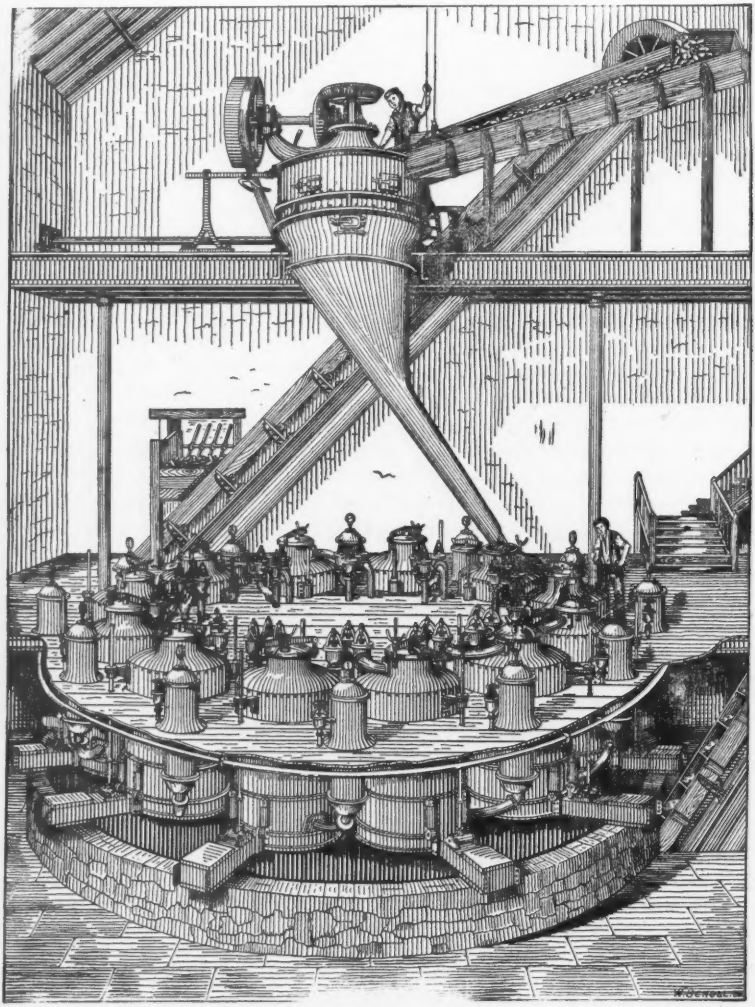

FIG. 21.—Diffusion battery.

The extracted cuttings are carried through a press by which a portion of the water is removed, and they are then in suitable condition for use as cattle food. The diffusion juices obtained as above described are

conveyed to carbonatation tanks, where they are treated with from 2 to 3 per cent of their weight of lime and afterwards with carbonic acid until nearly all of the lime is precipitated. The slightly alkaline juices are next passed through filter presses, by which the precipitated lime and other solid matters are removed. The juices pass next to a second set of carbonatation tanks, in which they undergo a treatment similar to that just mentioned, but the quantity of lime added is small as compared with that of the first carbonatation. The refiltered juices from the second carbonatation, usually termed the "saturation," are carried to the multiple-effect vacuum evaporator and reduced to the condition of sirup.

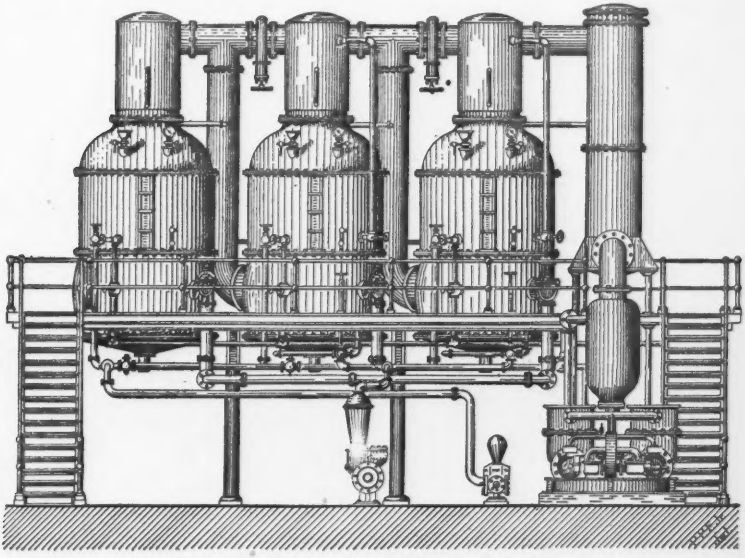

FIG. 22.—Multiple-effect evaporating apparatus.

The multiple-effect evaporating apparatus (fig. 22) consists of a series of pans connected in such a manner as to secure a progressively higher vacuum. The thin juices enter the first pan, where they are evaporated at a vacuum represented by a column of 0 to 8 inches of mercury. The steam with which this evaporation is effected is usually the waste coming from the engines and pumps of the factory.

The vapors generated in the first pan enter the heating pipes of the second one, and are thus utilized in evaporating the somewhat concentrated sirup which is drawn off from the first pan into the second one, where the vacuum is higher, being represented by a column of mercury of from 12 to 15 inches in height. The vapors which are produced in the second pan are in like manner conveyed to the heating pipes of a third apparatus, where the still more concentrated sirups from the

second pan are conducted and evaporated at the highest vacuum obtainable in such apparatus, usually from 26 to 28 inches of mercury. Usually a fourth pan is employed, but the arrangement is fully illustrated by the above example. It is easy to see by the arrangement above noted that the evaporation of the thin diffusion juices to a heavy sirup is accomplished with the greatest economy, direct steam being admitted only into the first pan, and the rest of the operation being accomplished by the steam generated in the evaporation of the liquors. The sirup thus produced is converted into sugar in the following manner:

A portion of the sirup is placed in an evaporating apparatus called the strike pan. This apparatus is very large, usually a cylindrical

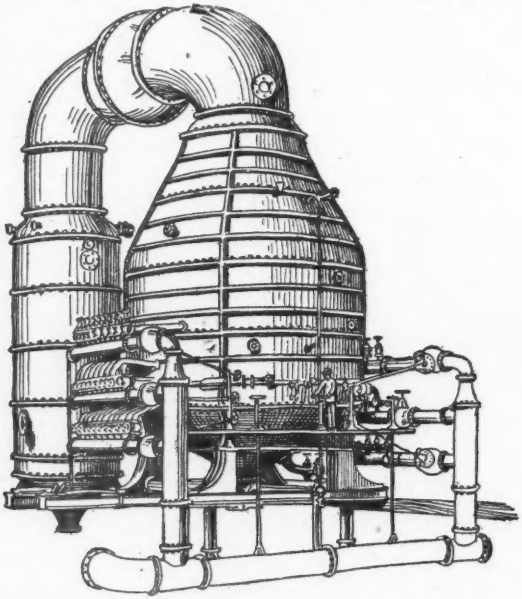

FIG. 23.—Vacuum strike pan.

vessel with a conical bottom, and is provided with a series of coils, one above the other, to which the steam can be admitted at will. The admission of steam is always so regulated that it is not allowed to enter any of the coils above the surface of the liquid in the pan. The portion of sirup first introduced is evaporated until it reaches a point of consistency which will permit of the formation of crystals, i. e., supersaturation. In this condition, if a portion of fresh sirup be introduced the whole mass in the pan becomes charged with exceedingly fine crystals of sugar.

By careful manipulation and the introduction of new quantities of sirup from time to time these crystals are made to grow. As the pan becomes full successive coils of the steam pipes are brought into use, so

that the boiling surface of the pan is gradually increased in proportion to the volume of its contents. In the course of a few hours the skilled sugar boiler will find that the pan is full and that the crystals have grown to the proper size. The mass in the vacuum pan at this stage is extremely heavy, consisting of a dense mass of sugar crystals mixed with a quantity of molasses greater or less in amount, as the juices from which the sugar is made are more or less pure. The illustration of the vacuum pan (fig. 23) is from a photograph of a large pan, 17 feet in diameter and 42 feet high, intended for refinery use. This pan turns out 1,000 barrels of sugar at each strike, and the time required for boiling is about three hours. It is constructed on exactly

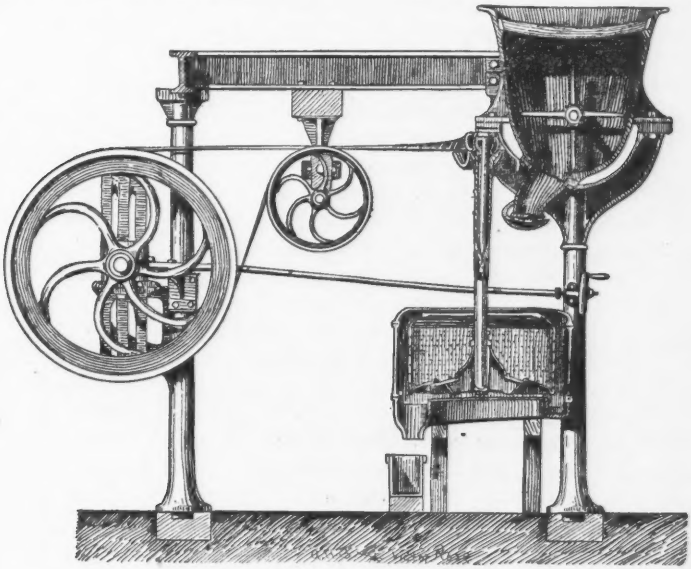

FIG. 24.—Centrifugal apparatus.

the same principles as the smaller pan employed in beet-sugar factories. In boiling sugar in a vacuum pan, if the highest possible yield is desired and no objection arises to the formation of soft crystals, a very high vacuum, equivalent to 29 inches of mercury at the sea level, is employed. At this vacuum the sirups boil at a temperature of from 112° to 120° F. If harder crystals, giving a somewhat less yield, are desired, as in the case of making granulated sugars, a lower vacuum, namely, from 24 to 26 inches, is employed.

The sirups are reduced in the vacuum strike pan into sugar called massecuite, which contains from 6 to 10 per cent of water. This is then carried directly to the centrifugals, where the molasses is separated.

The construction of the centrifugal apparatus is shown in fig. 24. A lining of wire gauze permits the molasses to pass outward under the impulse of the centrifugal motion, while it retains all the crystals of sugar except those fine enough to be entrained with the escaping liquid. The uncrystallized sirups, together with the water, are separated from the sugar by the centrifugals, and form the molasses. The molasses is reboiled and a second crop, and usually a third crop, of crystals obtained, the molasses from which is treated in various ways for separating the sugar which it still contains. One of these methods which has come into general use is known as the Steffen process. In this method the molasses is diluted with water cooled to a low temperature and treated with fresh-burned, fine-ground lime. The sugar in these conditions forms a chemical compound with the lime, which is separated from the other constituents of the molasses by means of a filter press. The lime sucrate thus secured is beaten up to a cream with water, the lime precipitated with carbonic acid, separated by means of a filter press, and the pure sugar juices thus obtained boiled for the separation of the sugar as described above. Another method consists in removing the salts which prevent the crystallization of the sugar by the process of osmosis. A third method consists in the use of strontium or barium hydroxid for the separation instead of lime salts, as in the Steffen process; or, finally, the molasses may be subjected to fermentation and distillation, and the sugar therein contained thus converted into alcohol.

The above is an outline of the general method used for the manufacture of raw sugar. If refined sugar is to be made, the juices and sirups may be passed over bone black to decolorize them and the crystals washed in the centrifugal in order to make them perfectly white. The small, hard, colorless crystals thus obtained when dried in a revolving drum form the granulated sugars of commerce. The customary method consists in treating the juices with sulphurous acid and purifying the crystals in the centrifugals.

HOME MANUFACTURE OF SUGAR.

The question is often asked if beet sugar can not be made in a small way so that farmers could club together, put up a cheap apparatus, and produce their own sugar. On account of the elaborateness of the process and the costly nature of the machinery which is necessary to produce beet sugar even in a small way, it is not believed that it could be profitably made in the way indicated. A small factory could not possibly compete with a large one, and hence there is no encouragement to be offered in the way of producing homemade beet sugar. The Department has no knowledge of any successful beet-sugar factory of this kind. There is no country producing any notable quantity of beet sugar in which home apparatus costing only a few thousand dollars has any appreciable influence on the output of sugar. Russia has

been cited as an exception to this rule. The output of beet sugar in Russia in 1898–99 was about 750,000 tons. The total number of factories in operation was about 300. The average annual output of each factory in round numbers was 5,000,000 pounds, representing an average consumption of 25,000 tons of beets. These figures indicate that the capacity of the average Russian beet-sugar factory is not greatly different from that of other European countries.

WASTE PRODUCTS.

The waste products of the factory consist of the pulps and molasses. The molasses is used for various purposes, either for making sugar, as described above, for fertilizing purposes, for the manufacture of alcohol, or sometimes for cattle food. The pulps make a valuable cattle food. They may be fed in the fresh state or preserved in silos. Lately extensive experiments have been made in drying the pulps and preserving them in the dried state, and these experiments have been fairly successful. It is stated that the value of the pulps for feeding purposes is from one-fourth to one-fifth of the value of the beets.

COST OF MANUFACTURE.

The cost of manufacture depends on as many factors as that of beet growing. Chief among these are transportation, fuel, weather, and labor. Perhaps the most important of these factors is the price of fuel. In some localities coal can be had for $1.25 per ton; in others the cost may reach as high as $10 per ton.

The manufacture of beet sugar is conducted without governmental supervision in this country, and any exact account of its cost is inaccessible. To show what it may be, with large experience and the highest skill and management, the mean cost of manufacture in 113 German factories is given:

Mean capital invested in each factory		$193,400.00
Total receipts for sugar, molasses, and pulps per ton of beets		11.10
Mean cost of beets per ton of 2,204.62 pounds	$4.90	
Salaries per ton of beets	.26	
Labor per ton of beets	.73	
Interest on investment per ton of beets	.36	
Coal per ton of beets	.63	
Miscellaneous expenses per ton of beets	.96	
Total expense of manufacture per ton		7.84
Profit per ton of beets		3.26

The mean net profit for each factory was $34,240. The price paid for beets, however, is in most cases fictitious, the beet growers owning the factory and preferring to share in the general profits rather than to charge a high price for the beets. First-class beets rarely sell for less than $5 per ton. The Western Beet Sugar Company, of Watsonville,

Cal., stated that in its first campaign, 1888–89, the cost of manufacture amounted to $80.80 per ton of sugar. At the present time it appears that with the best machinery, rich beets, and most economical processes beet sugar can be made in this country at a cost of less than 4 cents per pound when the price of rich beets does not exceed $5 a ton.

According to the report on the manufacture of beet sugar, Twelfth Census of the United States, the average price paid per ton of beets was as follows:

The United States	$4.39
California	4.47
Michigan	4.38
All other States and Territories	4.26

COST OF FACTORY.

The cost of building a first-class beet-sugar factory is much greater than is commonly supposed. From the most reliable data at hand it may be stated that in Europe the cost of erecting a factory with the most modern machinery, of a capacity of at least 300 tons of beets per day, is about $200,000. In this country it is probable that, owing to the higher price of labor, the cost of a similar factory would be at least $250,000.

The following data, from the report on beet-sugar manufacture in the United States, Bulletin 59, Twelfth Census, indicate the amount of capital required in establishing a factory:

Nominal daily factory capacity and capital invested per ton of beets.

States and Territories.	Number of establishments.	Total capacity in tons of beets per day.	Average daily capacity per factory.	Capital invested per ton of daily capacity.				
				Total capital.	Land.	Buildings.	Machinery and tools.	Cash and sundries.
		Tons.	*Tons.*					
United States	[1]31	[2]19,110	616	$1,097	$36	$204	$754	$103
California	[1]8	9,900	1,238	1,024	35	185	738	66
Michigan	9	4,100	456	979	35	226	589	129
All other	14	[2]5,110	364	1,334	87	224	921	152

[1] Includes one idle establishment.
[2] Includes one auxiliary factory at which no sugar is manufactured, but juice is extracted from the beets and pumped to a central factory for treatment.

In estimating the capital required in the organization of new companies for the manufacture of beet sugar, an assumed average capital per ton of beets, daily factory capacity, is frequently used as a factor. It is for this reason that these figures are included in the above table.

There are many conditions which modify the average capital invested per ton of nominal capacity. Among these are the following: (1) The cost of a large factory is less per ton of capacity than that of a small one; (2) freight charges for the transportation of machinery vary with the distance of the site of the factory

from the foundry in which the machinery is made; (3) the cost is necessarily greater in the case of those factories which are equipped for the recovery of sugar from molasses, from which no more sugar can be profitably extracted by the process of crystallization; (4) many factories have machinery of relatively small capacity so disposed in a large building as to permit of increasing the capacity of the plant without additional expense for buildings.

The Michigan factories were built within two years and under similar conditions in the iron market; with one exception, they are of American construction.

As has been intimated before, it is not advisable to attempt to manufacture beet sugar with smaller factories or with machinery and appliances which do not represent the latest improvements. It is true that there are many parts of a sugar factory which have not changed much within the last twenty years, but even the multiple-effect apparatus, the strike pans, and the centrifugals, which represent the most stable parts of the machinery, have undergone considerable changes within the time mentioned. Probably one of the greatest dangers which the beet-growing industry in this country will meet is the tendency to begin the erection of a beet-sugar factory with cheap, old, or worn-out apparatus and appliances and without a proper technical study of all the questions involved. The avoidance of this danger is all the more difficult, because there are few engineers in this country who have devoted themselves to the study of this problem, and European experts are not likely to understand and comprehend American methods and measures. Numerous inquiries have been received at this office for directions for making beet sugar with such appliances as a cider mill and sorghum-molasses evaporator might afford. It would not be right to encourage the attempt to manufacture beet sugar in any such way, nor should the expectation be excited among our farmers that they will be able to make a crude article of sugar which they can dispose of to a central factory for refining purposes. It is best to recognize at the very first the great expense which attends the erection of a sugar factory and the necessity for its meeting every modern requirement. Beet growing and beet-sugar manufacture are two distinct industries, but with common aims and interests.

COOPERATIVE FACTORIES.

It is seen from the foregoing paragraph that the farmer can have no reasonable hope of successfully establishing a home beet-sugar factory. It is not just, however, that he should be deprived of any cooperation in the process of manufacture or a reasonable share of the profits arising therefrom. The methods which have been practiced in Europe for securing these results are probably those which will eventually come into use in this country. The cooperative sugar factory, in which the farmers growing the beets hold a part or the majority of the stock, realizes the desired end. The growers of beets holding shares in the factory have a greater interest in its prosperity and try to

grow better crops and to secure in every way a higher yield. The cooperative factory renders impossible those disagreements between capital and agriculture which do so much to retard the progress of the industry and to embitter the feeling of the farmer against the factory. To show the extent of the participation of shareholders in factories in the growing of beets in Germany, it may be stated that of the 11,672,816 metric tons of beets delivered to the German factories in 1895–96, 2,689,004 tons were grown by shareholders. Inasmuch as the farmers in a beet-sugar community are uniformly prosperous, they are able to subscribe for shares in a factory and by a community of interests practically control its operations. The industry of growing beets is not yet sufficiently advanced in the United States to render possible any definite outline of the best plan of securing cooperation between the farmer and the capitalist. At the outset, it would probably be impossible to secure among the farmers alone a sufficient amount of capital to properly equip a factory. Even could this be done, the additional difficulty would be encountered of a lack of experience among the shareholders, leading to poor judgment in regard to the methods of conducting the manufacturing operations. As long as the proprietors of the factory and the farmers growing the beets are satisfied with the contracts which they make, there is no urgent necessity of the establishment of cooperative enterprises. When the number of beet-sugar factories in this country, however, begins to reach the hundreds, favorable opportunities of cooperative establishments will be presented.

STATISTICAL.

UNIT OF VALUE.

In the data giving the production and consumption of sugar the unit of value commonly employed is the ton. By reason of the fact that the ton in this country expresses a unit of varying magnitude a considerable degree of confusion is often introduced into statistical tables. In the following data, when not otherwise expressed, the term of ton is used as the representative of 2,240 pounds. The short ton, namely, 2,000 pounds, is a more convenient unit of expression, but is not used in the publication of sugar statistical data in this country. The metric ton, which is used on the continent of Europe, is a weight of 1,000 kilograms, equivalent to 2,204.62 pounds.

In the tables which follow some slight differences will be noted in data relating to the same subject. Their differences arise from the impossibility of securing exact statements relating to statistical data. Not having at hand the means of revising the statistical tables, it has been thought best to give the figures of the best authorities without attempting to harmonize them.

PRODUCTION OF BEET SUGAR IN THE UNITED STATES FROM 1830 TO 1901.

The following table, showing the production of beet sugar in the United States from 1830 to the present time, is taken from the Weekly Statistical Sugar Trade Journal for January 7, 1897, and January 5, 1901:

Production by years from 1830 to 1901.

1830	A few hundred pounds	1886	800 tons
1831–1837	None	1887	255 tons
1838–1839	1,300 pounds	1888	1,010 tons
1839–1862	None	1889	2,600 tons
1863–1871	300 to 500 tons per annum	1890	2,800 tons
1872	500 tons	1891	5,359 tons
1873	700 tons	1892	12,091 tons
1874–1877	Under 100 tons per annum	1893	20,453 tons
1878	200 tons	1894	20,443 tons
1879	1,200 tons	1895	30,000 tons
1880	500 tons	1896	40,000 tons
1881–1882	Less than 500 tons	1897–1898	[1] 40,399 tons
1883	535 tons	1898–1899	[1] 32,471 tons
1884	953 tons	1899–1900	[1] 72,944 tons
1885	600 tons	1900–1901	[1] 76,859 tons

[1] Tons of 2,240 pounds.

LOCATION OF BEET-SUGAR FACTORIES IN THE UNITED STATES.

The following beet-sugar factories are now (September, 1901) in operation:

Beet-sugar factories of the United States.

[From The Beet Sugar Gazette, Chicago, September, 1901.]

Name.	Location.	Daily capacity.
In operation.		
Eastern:		*Tons.*
Binghamton Beet Sugar Co	Binghamton, N. Y	600
Empire State Sugar Co	Lyons, N. Y	600
Michigan:		
Michigan Sugar Co	Bay City, Mich	500
Bay City Sugar Co	do	600
Detroit Sugar Co	Rochester, Mich	500
Wolverine Sugar Co	Benton Harbor, Mich	350
Peninsular Sugar Refining Co	Caro, Mich	600
West Bay City Sugar Co	West Bay City, Mich	750
Alma Sugar Co	Alma, Mich	600
Holland Sugar Co	Holland, Mich	350
Kalamazoo Sugar Co	Kalamazoo, Mich	500
Marine Sugar Co	Marine City, Mich	350
Western:		
American Beet Sugar Co	Rockyford, Colo	1,000
Colorado Sugar Manufacturing Co	Grand Junction, Colo	350
National Sugar Manufacturing Co	Sugar City, Colo	500
Ogden Sugar Co	Ogden, Utah	350
Utah Sugar Co	Lehi City, Utah	350
Utah Sugar Co. (rasping station)	Springfield, Utah	350
Do	Bingham Junction, Utah	350
American Beet Sugar Co	Grand Island, Nebr	350
Do	Norfolk, Nebr	350
Standard Beet Sugar Co	Leavitt, Nebr	500
Middle West:		
Minnesota Sugar Co	St. Louis Park, Minn	350
Illinois Sugar Refining Co	Pekin, Ill	700
Continental Sugar Co	Fremont, Ohio	350

Beet-sugar factories of the United States—Continued.

Name.	Location.	Daily capacity.
In operation—Continued.		
Pacific Coast:		*Tons.*
Oregon Sugar Co	La Grande, Oreg	350
Washington State Sugar Co	Waverly, Wash	350
Alameda Sugar Co	Alvarado, Cal	800
Spreckels Sugar Co	Watsonville, Cal	1,000
Los Alamitos Sugar Co	Los Alamitos, Cal	700
American Beet Sugar Co	Chino, Cal	1,000
California Beet Sugar and Refining Co	Crockett, Cal	1,200
Spreckels Sugar Co	Spreckels, Cal	3,000
American Beet Sugar Co	Oxnard, Cal	2,000
Union Sugar Co	Betteravia, Cal	500
Not in operation.		
Pecos Valley Beet Sugar Co	Carlsbad, N. Mex	200
Now building for the campaign of 1901.		
Lansing Sugar Co	Lansing, Mich	600
Saginaw Sugar Co	Saginaw, Mich	600
Western Construction Co	Loveland, Colo	1,000
Central Sugar Co	Shelbyville, Ind	500
Wisconsin Sugar Co	Menominee Falls, Wis	500
German-American Cooperative Beet Sugar Co	Salzburg, Mich	400
Logan Sugar Co	Logan, Utah	400
Now building for the campaign of 1902.		
Macomb Sugar Co	Mount Clemens, Mich	600

WORLD'S SUGAR CROP.

The total sugar crops of the world for the past four years, as given below, are rearranged from Willett & Gray's Weekly Statistical Sugar Trade Journal for August 15, 1901:

The world's sugar crop.

	1900–1901.	1899–1900.	1898–99.	1897–98.
Beet sugar:	*Tons.*	*Tons.*	*Tons.*	*Tons.*
United States	76,859	72,944	32,471	40,399
Europe	6,020,000	5,525,000	4,982,101	4,831,774
Total beet sugar production	6,096,859	5,597,944	5,014,572	4,872,173
Cane sugar:				
United States—				
Louisiana	270,000	132,000	245,511	310,447
Porto Rico	80,000	35,000	53,825	54,000
Hawaiian Islands	296,000	258,521	252,506	204,833
Cuba, crop	600,000	308,543	345,261	314,009
British West Indies—				
Trinidad, exports	50,000	41,000	53,436	53,000
Barbados, exports	60,000	50,000	45,787	49,835
Jamaica	30,000	27,000	27,000	30,000
Antigua and St. Kitts	25,000	18,000	22,000	25,000
French West Indies—				
Martinique, exports	35,000	30,000	31,630	31,469
Guadeloupe	35,000	30,000	39,390	37,136
Danish West Indies—St. Croix	13,000	12,000	12,000	13,000
Haiti and Santo Domingo	45,000	45,000	50,000	45,000
Lesser Antilles, not named above	8,000	8,000	8,000	8,000
Mexico, crop	93,000	78,000	50,000	
Central America—				
Guatemala, crop	9,000	12,000	11,000	9,000
San Salvador, crop	5,000	5,000	4,500	4,000
Nicaragua, crop	3,500	4,000	3,750	1,500
Costa Rica, crop	1,500	1,000	750	500
South America—				
British Guiana (Demerara), exports	95,000	80,000	82,000	106,000
Dutch Guiana (Surinam), crop	6,000	6,000	6,000	6,000
Venezuela	3,000	2,000		

The world's sugar crop—Continued.

	1900–1901.	1899–1900.	1898–99.	1897–98.
Cane sugar—Continued.				
South America—Continued.	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Peru, exports	105,000	100,381	61,910	101,577
Argentina, crop	114,252	91,507	72,000	110,000
Brazil, crop	178,000	192,700	154,495	200,478
Total cane sugar in America	2,160,252	1,567,652	1,629,760	1,717,784
Asia—				
British India, exports	15,000	10,000	10,000	20,000
Siam, crop	7,000	7,000	7,000	7,000
Java, crop	710,120	721,993	689,281	531,201
Japan (consumption 170,000 tons, mostly imported)		2,000		
Philippine Islands, exports	30,000	62,785	93,000	178,000
Total cane sugar in Asia	762,120	803,778	799,281	736,201
Australia and Polynesia—				
Queensland	97,650	124,871	164,241	97,916
New South Wales	19,000	15,500	28,000	26,000
Fiji Islands, exports	30,000	31,000	34,000	30,000
Total cane sugar, Australia and Polynesia	149,650	171,371	226,241	153,916
Africa—				
Egypt, crop	95,000	99,000	90,822	80,178
Mauritius and other British possessions	190,000	157,025	186,487	121,693
Réunion and other French possessions	35,000	35,000	37,781	31,483
Total cane-sugar in Africa	320,000	291,025	315,090	233,354
Europe—Spain	33,000	33,215	25,000	23,000
Total cane-sugar production (W. & G.)	3,425,022	2,867,041	2,995,372	2,864,255
The world:				
Grand total cane and beet sugar production	9,521,881	8,474,985	8,009,944	7,736,428
Estimated increase in the world's production	1,046,896			

In the above table is comprised the entire sugar production of all the countries of the world, including those crops which have heretofore been ignored in statistics. These figures include local consumptions of home production wherever known.

PRODUCTION OF BEET SUGAR IN EUROPE FOR FOUR YEARS, 1896–97 TO 1899–1900.

The quantities of sugar produced in Europe for four years, from 1896 to 1900, the last crop partially estimated, are as follows:

Sugar crops of several European countries.

[From Licht's Monthly Circular.]

Country.	1899–1900. Tons of 2,204 pounds.	1898–99. Tons of 2,204 pounds.	1897–98. Tons of 2,204 pounds.	1896–97. Tons of 2,204 pounds.
Germany	1,798,631	1,721,718	1,852,857	1,836,536
Austria	1,108,007	1,051,290	831,667	934,007
France	977,850	830,132	821,235	752,081
Russia	910,000	776,066	738,715	728,667
Belgium	304,000	244,017	265,397	288,009
Holland	171,029	149,763	125,658	174,206
Other countries	253,929	209,115	196,245	202,990
Total for Europe	5,523,446	4,982,101	4,831,774	4,916,496

NUMBER OF FACTORIES, YIELD OF BEETS PER ACRE, AND YIELD OF SUGAR IN THE PRINCIPAL BEET-SUGAR COUNTRIES OF EUROPE.

Germany.—Number of factories in operation during 1895–96, 397; quantity of beets used, 11,672,816 tons; hectares cultivated, 376,669 (acres, 930,372); mean yield per hectare, 31,000 kilos (pounds per acre, 27,669); mean price of beets per

metric ton, 17.70 marks (equal to $4.64 per ton of 2,000 pounds); yield of raw sugar (92 per cent) on weight of beets, 13.11 per cent; average output of sugar per factory, 4,068 metric tons.

France.—Number of factories in operation during 1895–96, 356; quantity of beets used, 5,411,484 metric tons; yield of refined sugar on weight of beets, 10.97 per cent; hectares under cultivation, 204,715 (405,852 acres); yield of beets in metric tons per acre, nearly 10.5; average output of sugar per factory, 1,876 tons.

Austria-Hungary.—Number of factories in operation in 1895–96, 215; quantity of beets used, 5,760,000 metric tons; yield of raw sugar (92 per cent) on weight of beets, 13.5 per cent; average output of sugar for each factory, 3,663 tons.

Russia.—Number of factories in operation during 1895–96, 277; quantity of beets used, 5,311,888 metric tons; per cent of sugar in beets, 15.71; average output of sugar for each factory, 2,828 tons.

CONSUMPTION OF SUGAR IN THE UNITED STATES.

The first of the following tables shows the consumption of sugar in the United States for each of the years 1900, 1899, and 1898, with a detailed statement of the origin of the sugar consumed, and the second is a statement of the consumption in the United States from 1881 to 1900, inclusive. The tables are taken from the Weekly Statistical Sugar Trade Journal of January 3, 1901.

Consumption of sugar in the United States during the years 1898, 1899, and 1900.

[Tons of 2,240 pounds.]

Source of sugar supply.	1900.	1899.	1898.
Meltings of the four ports	1,706,000	1,681,000	1,502,000
Of which were domestic from Louisiana crop	3,482	20,820	6,443
Meltings of foreign sugar through New Orleans	1,702,518	1,660,180	1,495,557
Foreign refined through Galvestou	131,309	72,066	9,431
		67	23
Total	1,833,827	1,732,313	1,505,011
Export of raw sugar from Atlantic ports	45	1,818	1,450
Export of refined sugar from Atlantic ports	6,042	14,984	4,192
Total exports to be deducted	6,087	16,802	5,642
Consumption of foreign sugar through Atlantic ports	1,827,740	1,715,511	1,499,269
Consumption of foreign sugar through San Francisco	132,274	124,131	139,668
Total consumption of foreign sugar	1,960,014	1,839,642	1,638,937
Louisiana crop consumed during the year	168,000	155,000	245,612
Texas crop consumed during the year	6,450	5,400	7,200
United States beet sugar consumed during the year	82,736	62,826	34,453
United States maple sugar consumed during the year	5,000	5,000	5,000
Molasses sugar made in United States from foreign molasses	7,647	5,200	1,700
Total consumption of domestic sugar	269,833	233,426	293,965
Grand total	2,229,847	2,073,068	1,932,902
Add undistributed refined brought over from previous years	20,000	25,000	95,000
	2,249,847	2,098,068	2,027,902
Deduct undistributed refined carried over to next year	30,000	20,000	25,000
Total consumption of all sugar, in tons of 2,240 pounds	2,219,847	2,078,068	2,002,902

Consumption per capita is 66.6 pounds in 1900, 61 pounds in 1899, 60.3 pounds in 1898, 63.7 pounds in 1897, 60.9 pounds in 1896, 64.23 pounds in 1895, 66.64 pounds in 1894, 63.83 pounds in 1893, 63.76 pounds in 1892, 67.46 pounds in 1891, 54.56 pounds in 1890, 52.64 pounds in 1889, 54.23 pounds in 1888, 53.11 pounds in 1887, 52.55 pounds in 1886, 49.95 pounds in 1885, and 51 pounds in 1884.

Consumption of sugar in the United States during the years 1881 to 1900, inclusive.

Year.	Total consumption of United States.	Increase (+) or decrease(—).	Year.	Total consumption of United States.	Increase (+) or decrease (—).
	Tons.	*Per cent.*		*Tons.*	*Per cent.*
1900	2,219,847	+ 6.82	1890	1,522,731	+ 5.80
1899	2,078,068	+ 3.75	1889	1,439,701	— 1.21
1898	2,047,444	— 1.16	1888	1,457,264	+ 4.62
1897	2,071,413	+ 6.90	1887	1,302,909	+ 2.73
1896	1,940,086	+ 0.53	1886	1,355,809	+ 8.11
1895	1,949,744	— 3.27	1885	1,254,116	+ 0.14
1894	2,012,714	+ 5.08	1884	1,252,366	+ 7.0
1893	1,905,862	+ 2.83	1883	1,170,375	+10.3
1892	1,853,370	— 1.102	1882	1,061,220	+ 6.8
1891	1,872,400	+22.96	1881	993,532	

Increase for nineteen years, 123.43 per cent, or 6.34 per cent per annum.

CONSUMPTION OF SUGAR PER HEAD.

The following tables, taken from the Weekly Statistical Sugar Trade Journal, shows the consumption of sugar in pounds per head for all the countries of Europe and for the United States for four years from 1891–92 to 1894–95:

Consumption of sugar for the United States and all the countries of Europe for 1891–92 to 1894–95.

Country.	Population 1895.	1894–95.	1893–94.	1892–93.	1891–92.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*
Germany	51,650,000	26.78	26.71	22.90	23.56
Austria	43,456,000	19.81	16.57	17.20	16.05
France	38,800,000	30.61	27.80	27.86	30.46
Russia	100,239,000	10.94	11.06	10.94	10.34
Holland	4,732,000	31.30	25.55	22.90	26.88
Belgium	6,325,000	22.50	21.73	21.09	21.29
Denmark	2,300,000	45.41	42.96	43.53	43.63
Sweden and Norway	6,873,000	24.95	24.82	23.64	24.14
Italy	30,724,000	6.65	7.07	7.00	7.18
Roumania	5,800,000	4.03	4.07	4.53	3.90
Spain	17,650,000	13.68	12.47	12.38	11.06
Portugal and Madeira	5,082,000	12.92	13.09	12.51	12.43
England	38,927,000	86.09	84.78	77.40	80.73
Bulgaria	3,310,000	8.88	7.14	6.07	5.16
Greece	2,235,000	6.26	7.29	7.38	8.62
Servia	2,256,000	4.01	4.25	4.22	3.81
Turkey	21,983,000	7.65	7.25	7.64	9.30
Switzerland	2,895,000	44.66	42.30	31.62	31.30
Europe	385,177,000	25.64	23.25	22.02	22.64
United States	69,753,000	62.60	66.64	63.83	63.76
Total	454,930,000	31.07	29.33	28.20	29.00

We give below figures showing the consumption of sugar per capita in the various countries of Europe and in the United States:

Consumption of sugar per capita, 1899–1900.

Country.	Population, 1900.	Consumption per capita, 1899–1900.
Germany	55,835,000	33.9
Austria	46,335,000	17.6
France	38,565,000	36.9
Russia	107,000,000	14.0
Holland	5,075,000	32.4
Belgium	6,670,000	23.3
Denmark	2,364,000	54.8
Sweden and Norway	7,175,000	38.2
Italy	31,856,000	6.1
Roumania	5,612,000	7.8
Spain	18,200,000	10.6
Portugal and Madeira	5,110,000	14.7
England	40,708,000	91.6
Bulgaria	3,316,000	7.7
Greece	2,465,000	7.2
Servia	2,413,000	5.2
Turkey	24,515,000	8.0
Switzerland	3,145,000	62.3
All Europe (Licht)	401,359,000	27.1
United States of America (W. & G.)	74,627,907	66.6

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN 52.

Rev.ed.
follows

THE SUGAR BEET:

CULTURE, SEED DEVELOPMENT, MANUFACTURE, AND STATISTICS.

BY

H. W. WILEY,
Chief of the Bureau of Chemistry, and formerly Director of the Department Sugar Beet Experiment Station in Nebraska.

[Third Revised Edition, August, 1908.]

By A. HUGH BRYAN,
Sugar Laboratory, Bureau of Chemistry.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY,
Washington, D. C., August 17, 1908.

SIR: I have the honor to transmit for your approval the third revision of Farmers' Bulletin No. 52, on the sugar beet, prepared by Mr. A. H. Bryan, chief of the sugar laboratory, who has had practical experience in the beet-sugar industry. This bulletin was last revised in 1901, having been originally issued in 1897, and first revised in 1899. Extensive changes have been made in the text that the most recent practices in sugar-beet culture might be given; references to the work of the Bureaus of Entomology and Plant Industry, bearing on diseases of the sugar beet, pests attacking it, and the development of the single-germ seed have been inserted, and the statistics have been brought up to date. It is hoped that the bulletin in its revised form may prove as useful as its predecessors to those interested in the extension of this industry, the demand for this information having continued during the past nine years.

Respectfully,

H. W. WILEY, *Chief.*

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THE SUGAR BEET.

INTRODUCTION.

The successful growing of sugar beets is an art that one acquires by practice. The farmer who has made a success of raising other crops will quite often fail at first in this one, as the methods of cultivating ordinary crops do not apply in the case of sugar beets. Certain directions for the preparation of the soil, the planting, thinning, and harvesting must be followed in beet culture. Although it is possible to raise sugar beets with little regard to these directions, such a crop will usually fail to pay for itself either because the yield is too small or the sugar content of the beets too low to meet factory requirements. In commercial beet growing, therefore, carelessness leads quickly to failure, while careful regard for details spells success. Success comes at first from following the advice of successful growers, and later it may be augmented by practical experience. Certain economies can be practiced, but they should never consist in planting a smaller quantity of seed than is prescribed, nor in locating the beet field on poor land.

In the manufacture of sugar from the beet, the farmer plays an important part by supplying beets in an adequate quantity and of a high quality; but beyond that he can hardly hope to enter the field. The manufacture of beet sugar is an industry entirely distinct from agriculture, and can only be successfully accomplished by the investment of large capital and the employment of skilled artisans. From the nature of the process it is quite improbable that any simple method of home manufacture of beet sugar will ever prove commercially successful. The juice of the beet is extracted with difficulty. It contains considerable quantities of mineral salts and organic substances, which render the crude sugar and molasses therefrom unpalatable. Simple processes for the extraction of the juice can at best remove only 60 to 70 per cent of the sugar which the beet contains, and thus a percentage of loss is incurred which at the very outset renders it impossible for a home apparatus to compete with a large factory. Beet sugar, for the reasons given above, can not be used in the raw state, as is the case with the products derived from the sugar cane, sorghum, and the maple tree. The refining of the sugar requires a heavy outlay for machinery and a high degree of supervisory skill. It can not, therefore, be accomplished upon the farm.

The beet-sugar industry offers a great opportunity for the profitable extension and diversification of agricultural industries in this country. The sugar beet is proving a profitable crop for the farmers not only in old settled areas where it must compete with a large list of established crops, but in the newly developed regions of the West where its adaption to intensive farming makes it a favorite crop for culture under irrigation. Its influence in developing stock breeding, feeding, and dairy industries is attracting the favorable attention of farmers interested in these pursuits. The rapid extension of the industry during the past few years shows that its value is gaining recognition; and there appears to be no valid reason why this extension should not continue until all the sugar consumed in the United States is made from crops grown by American farmers.

TEMPERATURE CONDITIONS AFFECTING THE BEET-SUGAR INDUSTRY.

Experience has shown that the sugar beet reaches its highest development in north temperate latitudes. So far as the production of beets with high tonnage is concerned, it is found that this can be accomplished far to the south, but beets grown there are, on the whole, less rich in sugar and less suitable for the manufacture of sugar than those grown farther north. It must be remembered, however, that the expressions north and south do not refer to any absolute parallels of latitude, but rather to isothermal lines, which in many cases vary widely from the parallels of latitude and in some cases cross them almost at right angles.

Theoretical beet-sugar belt.—As a result of many years of careful experimentation, it may be said that as far as temperature alone is concerned the sugar beet attains its greatest perfection in a zone of varying width through the center of which passes the isothermal line of 70° F. for the months of June, July, and August. This zone for this country is shown in the accompanying map (fig. 1).

This isothermal line, for the United States, begins near the city of New York and passes up the Hudson River to Albany; thence turning westward, it runs near Syracuse and passes in a southwesterly direction, touching the shore of Lake Erie near Sandusky, Ohio; turning thence in a northwesterly direction, it enters Michigan and reaches its highest point in that State near Lansing; then going in a southwesterly direction, it enters the State of Indiana near South Bend, passes through Michigan City, then in a northwesterly course continues through the cities of Chicago and Madison, reaching its highest point near St. Paul, Minn.; thence it extends in a southwesterly direction until it enters the State of South Dakota, where it turns again northwest and reaches its highest point in Dakota just above the forty-fifth parallel of latitude, where it crosses the Missouri River. The iso-

thermal line then turns almost due south, following very closely the one hundred and first degree of longitude until it leaves the State of

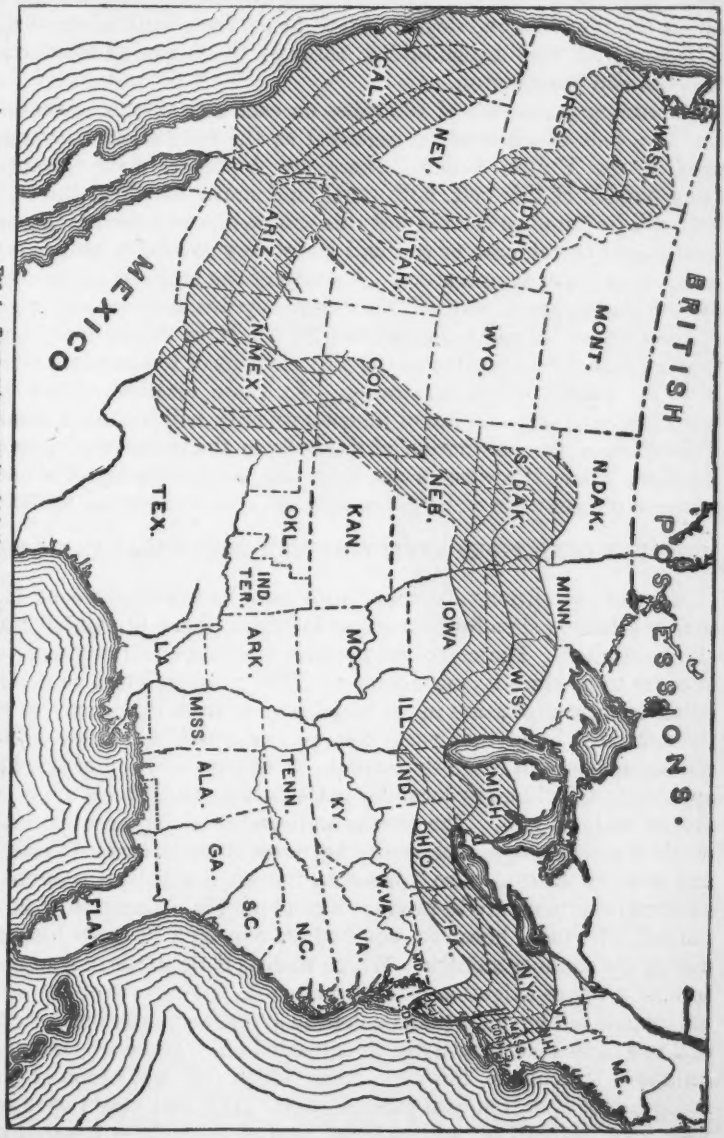

FIG. 1.—Temperature zone in which the sugar beet attains its greatest perfection.

Nebraska near the northeast corner of Colorado; passing in a southwesterly direction through Colorado, it reaches, at Pueblo, almost to

the one hundred and fifth degree of west longitude, whence it passes in a slightly southeasterly direction into New Mexico, turns to the west, and crosses the one hundred and fifth degree of longitude at about the thirty-second degree of latitude. Then turning westward, it passes in a very irregular line through the States of California, Oregon, and Washington.

Extending a distance of 100 miles on each side of this isothermal line is a belt which may be regarded as the theoretical beet-sugar area of the United States. There are doubtless many localities lying outside of this belt, both north and south, in which the sugar beet will be found to thrive; but this will be due to some exceptional qualities of the climate or soil and not to any favorable influence of a higher or lower temperature. A study of the location of the sugar factories operating to-day will show that only five factories are outside of these lines. A mean temperature of 70° F. in the summer, however, must not be regarded as the only element of temperature which is to be taken into consideration. In those localities where the winters come early and are of unusual severity will be found greater difficulties in the production of sugar from the sugar beet than in localities where the winters are light and mild, although the mean summer temperature of both localities may be represented by 70° F.

MOISTURE CONDITIONS AFFECTING THE BEET-SUGAR INDUSTRY.

Although conditions of temperature must be taken into consideration in selecting sites for beet-sugar factories, those of rainfall must also be studied. The sugar beet requires a certain amount of moisture in order to produce its normal crop. This moisture must be derived either from precipitation in the usual way or from irrigation; or else the soil must be of that particular quality which will allow subterranean moisture to reach the rootlets of the plants. Soil of this kind appears to exist in many localities in California, where beets are grown almost without rain. The porous and sandy soils adjacent to many of the Western rivers, such as the Arkansas River in eastern Colorado and western Kansas, also appear to furnish a sufficient amount of subterranean moisture to produce a good crop in connection with the rainfall, of which, however, but little is expected in those localities during the summer months. Where there is little subterranean moisture, and where irrigation is not practicable, the culture of the sugar beet should not be undertaken unless an average summer precipitation of 2 to 4 inches per month can be depended on. There are many conditions of agriculture, however, under which the beet becomes quite independent of extremes of precipitation. The beet may thrive with very little rainfall or with a great deal, if properly cultivated in a suitable soil.

GROWING BEETS ON IRRIGATED LANDS.

The experience of more than twenty years in California and eight years in Colorado has shown that the climatic data, regarded as of prime importance in beet culture in Europe, can not be regarded as rigidly applicable to this country. The successful growth of sugar beets in the arid regions of our country, with irrigation, has introduced a new factor into the science of beet meteorology. While the arid area on which beets can be grown without irrigation is probably confined almost exclusively to the coast valleys of California, the successful commercial production of sugar beets in Utah and Colorado has opened a new and extensive field. What has taken place in these States is being rapidly duplicated in Idaho; a beginning has been made in Montana, and the time is undoubtedly coming when beets will be grown in Wyoming and probably throughout the whole arid region.

FIG. 2.—Kleinwanzlebener sugar beet.

The northern parts of our Eastern and Middle States and the States of Oregon and Washington have at least an equal chance for the successful production of beet sugar with the fields of Germany and France. The irrigable parts of the great Southwest have advantages of soil and climate which will enable them to enter into competition in the production of beet sugar. To be able to control the moisture of the soil is a matter of prime importance to the beet grower. In the arid region the time at which the beet matures can be controlled by withholding the water. Furthermore, there is no danger of loss due to second growth, so easily induced by late warm autumnal rains.

The high cost of good irrigation renders it imperative that the areas under culture be devoted to a crop which is capable of producing a

more valuable yield than is afforded by cereal culture. In a dry soil the beet can endure without damage a low temperature, which would prove quite disastrous in a wet climate. More complete maturity may be thus obtained, and a more leisurely harvest. In fact, there is no staple crop which can compete with the sugar beet in demanding the favorable attention of those interested in irrigation. If a net profit of from $10 to $20 per acre can be secured, from $100 to $200 per acre can be paid for the land. It is estimated that nearly 80,000,000 acres of land in the arid regions of the United States may eventually be irrigated, being nearly one-fifth of the total area. Of this area perhaps 10 per cent is capable of easy and speedy irrigation. One million acres planted to beets would yield, under intensive culture, a quantity of sugar sufficient, with the Louisiana product, for domestic consumption. There is nowhere in sight a more promising prospect for agricultural development than in the production of sugar beets on irrigated lands.

VARIETIES OF BEETS.

Botanically all kinds of sugar beets are of the same species as the common garden beet (*Beta vulgaris*). The differences between varieties have arisen from selection and breeding. Certain valuable peculiarities resulting from natural variations or mutations have, through careful selection, been *fixed*, and pure strains having these superior qualities associated with certain distinguishing external characters have been developed.

The shape and size of the beet, its color, the character of the foliage, whether erect or spreading, etc., are the most frequent marks of distinction. The beets are also frequently designated by the names of those who have developed them, or by the name of the town or locality in which they have been grown.

Among the more frequently occurring varieties grown in Europe may be mentioned the Improved Kleinwanzlebener, the Kleinwanzlebener, and the Vilmorin, the two latter being most widely known in this country. Sugar manufacturers prefer those varieties which yield a high percentage of sugar, since the juices are purer and the expenses of manufacture and the cost of the raw material are less. Large beets yielding a large tonnage were usually grown in Europe prior to the adoption of legislation placing a tax on the beet itself instead of on the sugar, and were preferred on account of the value of the pulp for cattle feeding.

The certainty that the seed has been grown according to the most scientific methods is of great importance to the beet grower and sugar manufacturer, since the former may depend upon producing rich beets and receiving fair compensation for his labor and the latter is enabled to operate his factory economically. The beet has reached

such a high state of perfection as to make the least degree of laxity in its treatment exceedingly dangerous to its qualities.

The best beet for general cultivation is probably the Kleinwanzlebener, which seems now to have a wider cultivation in this country than any other variety. The general character of this beet is shown by figure 2. It has a conical root, straight and even, quite large at the head and rapidly tapering, and is distinguished from the Improved Vilmorin by its brighter color and its lighter-colored leaves, which are beautifully undulating or scalloped about the edges. Coming from a cross in which the Improved Vilmorin entered largely, the Kleinwanzlebener is to-day a fixed variety and is equally well produced in France and Germany. It succeeds in soil of an alluvial nature and average richness and on level plateaus. In soils very rich in humus it ripens poorly and loses much of its richness. Like the Improved Vilmorin, toward the end of the growing season its leaves are completely spread. Under those conditions of culture where the Improved Vilmorin gives from 12 to 16 tons per acre, the Kleinwanzlebener gives from 14 to 18 tons; and from these beets 13 to 18 per cent of sugar can be obtained.

FIG. 3.—White Improved Vilmorin sugar beet.

The other general type, the Vilmorin, is illustrated in figure 3. This beet is the result of thirty-five years of methodic and persevering selection based upon the lines to be indicated hereafter. In regard to its preservation, it is recognized that it holds its sugar content as well as any other variety. In those factories in Germany and France in which sugar is manufactured from the Improved Vilmorin in connection with other varieties it is the custom to reserve this variety for the end of the season and to work up the less reliable beets at an earlier date. It is also said to resist better than any other

variety the unfavorable influence of certain characters of soil and of certain manures. In black soils, rich in organic matter, it gives great results, while most other varieties of beets become watery or saline in excess. Excessive quantities of nitrogenous fertilizers, which are carefully excluded from ordinary varieties, can be applied with safety to the Improved Vilmorin; a great number of experiments have shown that this can be done without serious deterioration in the quality of the beet and with a considerable increase in weight. However, experiments with Kleinwanzlebener beets show that they are also susceptible to the influence of such fertilizers, as is shown by a gain in tonnage when fertilized. From thousands of analyses it has been established that about 16 per cent of sugar can be obtained with the Vilmorin and that under favorable conditions from 12 to 16 tons per acre can be raised.

In this country considerable quantities of beet seed have been grown at Fairfield, Wash., and also by the Utah-Idaho Sugar Company in Utah and Idaho chiefly, in the latter case, for its own use. In California and Michigan also some seed is produced.

Within the last four years the Department of Agriculture has been doing considerable work in endeavoring to develop a strain of beets bearing single-germ seed balls (see p. 30) and in growing seed better adapted to the requirements of this country. Considerable progress has been made along these lines. The farmer growing beets for a factory does not have to consider these points to any great extent, as the factories buy the seed and then furnish it to their growers. It is of prime importance that the factory purchase the best seed, and they are better able to judge as to the kind of seed desired and to test its vitality.

CULTURE OF SUGAR BEETS.

Farmers who raise beets for a sugar factory are not left entirely to their own resources in growing the crop. They enter into a contract with the factory management which outlines the methods to be employed. Then the factory employs an agricultural superintendent and a corps of assistants whose duty it is to go among the growers giving instructions and suggestions regarding the selection and preparation of the soil, planting, cultivation, time of harvesting, etc. These men are of course well informed on all phases of beet culture, and they are usually able to make valuable suggestions in regard to the cultivation of other crops grown in rotation with beets. Their instructions and influence, therefore, tend to improve the farm practice of communities in which sugar beets are grown.

SELECTION OF SOIL.

The sugar beet does not require a particular kind of soil for its proper production. In general, soils are described for practical purposes as clayey, sandy, loamy, or alluvial soils; all of these soils will produce beets. The black prairie soils also have been found, with proper cultivation, to produce excellent beets. Perhaps the best soil may be described as a sandy loam, a soil in which there is a happy equilibrium of organic matter, clay, and sand.

New land should not be selected to grow sugar beets, for the crop is not a good reclaimer of soils; and especially to be avoided is new land containing decaying vegetable matter, which produces only rank growth with low sugar content. Preferably the most productive land on the farm should be used, such a soil as will yield a good crop of Indian corn, wheat, or potatoes. The soil should neither be so compact as to interfere with cultivation to a depth of 10 or 12 inches nor have a tendency to bake hard. It may contain some alkali, as sugar beets are not especially susceptible to injury from this constituent. The soil should be reasonably level, but it should also be well drained. Natural drainage on level soil being somewhat deficient, tile drainage may be practiced with advantage.

FERTILIZATION.

Happily, in most American soils there is still sufficient natural fertility to produce a good crop of sugar beets; whereas in the soils of Europe, where sugar beets have been grown for years, the farmers must depend on fertilizers to insure a remunerative crop.

The principles of fertilization depend upon the fact that a soil should have returned to it all that the harvest has removed, and an unproductive soil be supplied with those elements in which it is deficient.

The soil ingredients most essential for the successful production of sugar beets are nitrogen, phosphoric acid, potash, and lime.

The following are the quantities of these constituents in 1,000 pounds of beet roots and in an equal quantity of beet leaves, as determined by numerous analyses:

Constituents.	In 1,000 pounds of roots.	In 1,000 pounds of leaves.
	Pounds.	*Pounds.*
Potash	3.3	6.5
Phosphoric acid	0.8	1.3
Nitrogen	1.6	3.9
Total ash	7.1	18.1

It will be seen from the foregoing table that, for equal weights, the leaves make a heavier drain on the plant-food elements of the

soil than do the roots. The disposition to be made of the leaves is therefore a matter of considerable importance. By leaving them on the land the plant-food elements which they contain will be returned to the soil. If they are removed for feeding, the need for applications of commercial fertilizers is increased. The leaves may, however, be fed and the resulting manure may be returned to the soil without material loss of these fertilizing constituents; or in some cases stock may be turned into the beet fields to feed on the tops and leaves remaining on the ground after the harvest is completed.

Most soils contain a sufficient quantity of lime, although there are some in which the supply of lime is naturally deficient; and such soils would be benefited by an application of land plaster, burned lime, phosphatic slags, or ground shells. Phosphoric acid and potash are supplied in the form of ordinary commercial fertilizers—the phosphorus as ground bone, superphosphate, or basic slag, and the potash may be supplied in the form of muriate or sulphate of potash or as kainit.

Nitrogen may be supplied in the form in which it exists in ground bone, or from the refuse of the slaughterhouses in the form of dried blood and tankage, or as cotton-seed meal or oil cake, or as nitrate of soda, sulphate of ammonia, etc.

Barnyard manure offers a ready means for fertilizing the soil, and one which every farmer can employ. By its use, humus is added to the soil as well as small percentages of potash, phosphoric acid, and nitrogen. There is a great difference of opinion as to the best time and method for applying it to beet land. In general, however, it should be applied, in a well-rotted condition, in the autumn before the ground is plowed. The quantity per acre depends, of course, on the fertility of the soil; but in any case it is not best to apply a very heavy dressing. With poor soils it is best to apply the manure for several years in succession, rather than to apply enough at once to bring it up to the required state of fertility. Too copious an application of manure is apt to produce overgrowth in the beets, which makes them ill suited to the manufacture of sugar. If the manure be applied in an unrotted condition it is apt to seriously injure the crop in case of dry weather.

As to the relation which the quantity of material returned to the soil should bear to the quantity abstracted by the beet, it may be said in general that it is desirable to return as much nitrogen, from one and a quarter to one and a half times as much potash, and two and a half times as much phosphoric acid as have been removed by the roots. Greater additions of potash and phosphoric acid have no disadvantageous effects upon the crop. But it must not be expected, on the other hand, that increasing fertilization, especially

with potash, will produce proportionately increasing crops, as has been asserted by some.

As regards the use of nitrate of soda for fertilization, if applied late to the beet crop, it prevents its ripening, thereby lowering the sugar content. It is best applied early and in small quantities. Heavy applications are thought to injure the beet for manufacturing purposes.

CROP ROTATION.

Every farmer should understand that he can not continuously grow any crop on the same ground and secure maximum results. Many try to do this, but they do it to their own loss and the depletion of the soil.

One of the great objects of crop rotation is to bring about and maintain an equilibrium of soil constituents and conditions. The best rotation is the one in which the method of culture and action of the plant each year leave the soil in the best condition for the following crop. Beets do best after alfalfa, corn, or small grains.

A good scheme of rotation is, first, wheat; then beets; then clover for two years, the last crop being plowed under; then potatoes, wheat, and beets in the order mentioned. If alfalfa can be grown, it should be included in the rotation of crops. Also in some sections potatoes do well in the rotation. By this method, and a judicious use of stable manure and commercial fertilizers, the fertility of the soil can be maintained and even increased. Beets do well after small grain crops, because these, being harvested early, leave the ground ready for late autumn plowing, an important point in successful beet culture.

PREPARATION OF THE LAND FOR PLANTING.

The field in which beets are to be planted should be selected and plowed in the late autumn to the depth of at least 9 inches. As a rule the plow in each furrow should be followed by a subsoiler, which will loosen the soil to the depth of 6 or 7 inches more. A convenient subsoil plow is shown in figure 4. Each field to be planted in beets should thus have the soil prepared by thoroughly loosening it to the depth of from 15 to 18 inches. The land, being exposed through the winter, becomes quite mellowed, and in the spring can in many cases be prepared for planting by thoroughly cultivating the surface of the soil until it is reduced to perfect tilth. The large cultivator shown in figure 5 can be conveniently used for this purpose, followed when necessary by a harrow and roller. Too much can not be said of the importance of correct preparation of the ground before seeding, as on this condition the crop depends to a large extent. The seed bed should be uniformly well pulverized. It is desirable, however, that

each portion of the field to be planted should be thoroughly prepared immediately before the planting takes place. For instance, if the planting is to be made on a given day, the soil should be thoroughly

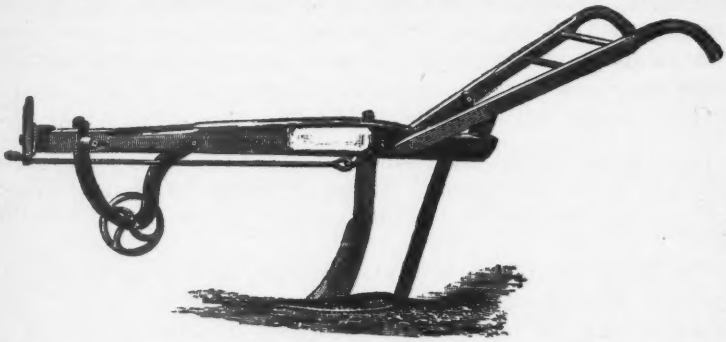

FIG. 4.—Subsoil plow.

prepared on the previous day. Thus all weeds and grasses which have started to grow are killed, and the beets have an even chance with the weeds for growth. If, on the other hand, the soil be prepared a week or even a few days before planting, the weeds and

FIG. 5.—Cultivator for sugar beets.

grasses get a good start, and it is difficult to free the beets therefrom. In case the ground has to stand any time before seeding after being prepared, it should be constantly and thoroughly cultivated.

PLANTING THE SEED.

Hand planting of the seed may be practiced when a very small plat is to be put in beets, but where a field embracing an acre or more is to be planted it is not convenient. In such cases planting by drill is best. Almost any garden drill can be adapted to use with beet seed. Special drills for sugar-beet seed are made by many manufacturers of agricultural implements. In planting by drill it is necessary to use from 15 to 20 pounds of seed per acre; in planting by hand from 10 to 15 pounds will be found sufficient.

A very convenient hand drill, which is especially fitted with a beet-seed dropping apparatus, is shown in figure 6. This machine marks the row, excavates the furrow, drops the seed at any required distance, and covers it.

FIG. 6.—Hand seed drill.

The beets should be covered to a depth of one-half inch to 2 inches, according to the state of the soil. If the soil be moist and in excellent condition, the beet seed should not be covered more than half an inch. If, on the other hand, the soil be very dry and early rains are not probable, the seed should be covered to a depth of 2 inches.

In the matter of space between rows there is considerable variation. In some cases the rows are made only 16 inches apart, and in others as wide as 28 inches. In recent years the tendency has been to increase rather than diminish the distance, though much depends on the soil and local conditions. It is argued by many that the greater ease and economy of culture with the wider rows outweigh the increased yields per acre which may be secured in the narrower rows.

When a considerable acreage is planted, it is important to be able to plant two or more rows at a time. The accompanying illustration (fig. 7) shows a seed drill which plants four rows at once.

In planting by hand or by drills an effort should be made to drop the seeds singly and at equal distances apart.

Under irrigation planting can be accomplished at almost any time, as the ground can be irrigated, then cultivated, and the seed planted at once.

Beets should be planted as early in the spring as practicable, but the ground should have sufficient moisture and warmth to cause germination of the seed. Experience has shown that the early-planted beets almost uniformly produce a larger yield with a higher content of sugar than the late-planted. No exact date can be fixed which would be suitable to all localities. In most of the localities in

FIG. 7.—Four-row seeder.

the beet area or the United States it will not be found practicable to plant earlier than the first week in May. In exceptional seasons a part of the sowing can be accomplished in April. On the Pacific coast, especially in central and southern California, the sowing can take place at a much earlier date. In parts of California planting is done in December with favorable results. But if planted too early, some of the beets will go to seed before harvest time. When this happens the percentage of sugar is diminished.

Most factories, by way of inducement to early planting, offer free seed for replanting any beet fields that may be injured by frost or other unfavorable conditions. This early planting makes it possible for the factory to begin its campaign earlier in the fall.

CULTIVATION.

To prevent the formation of a crust, and to keep the weeds and grass from getting a start, it is often necessary to cultivate the beet field with a spike harrow before the plants come up and to continue such cultivation until the beets are large enough for row cultivation to begin. Cultivation must not be postponed or neglected unless wet ground makes it impossible. The purpose of cultivation is two-

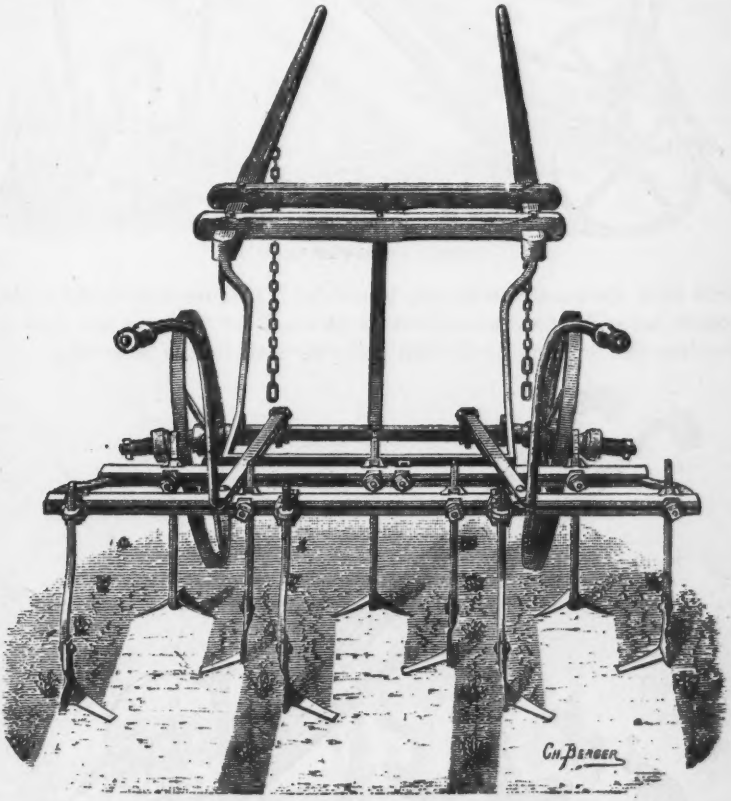

FIG. 8.—Horse hoe.

fold: (1) To hold the moisture in the soil; (2) to destroy the weeds and grass, as in the early stages of the beet's growth these can spoil the stand by choking the plants. When the land becomes dry is the most important time for cultivation in order to prevent the escape of moisture from the soil. Cultivation should be continued until the beets have attained such a size that the leaves cover the ground.

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When large fields are cultivated, the horse hoe, a model of which is shown in figure 8, may be used. For smaller fields a similar apparatus propelled by hand may be employed. Convenient implements of

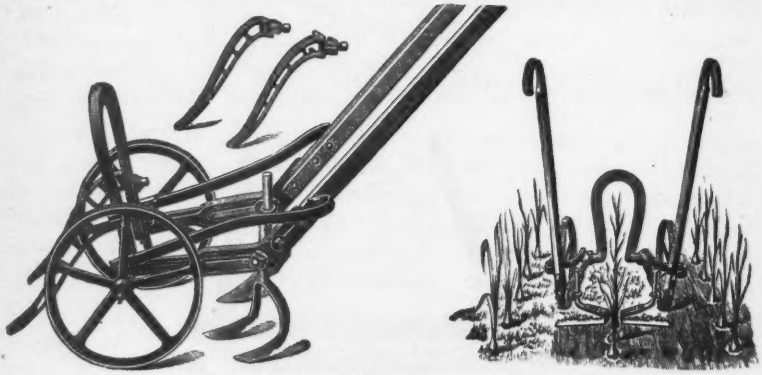

FIG. 9.—Hand-wheel hoes.

this kind are shown in figures 9 and 10. This implement frees the spaces between the rows of beets from weeds, and guards are used to prevent the growing beets from being covered by the loose soil.

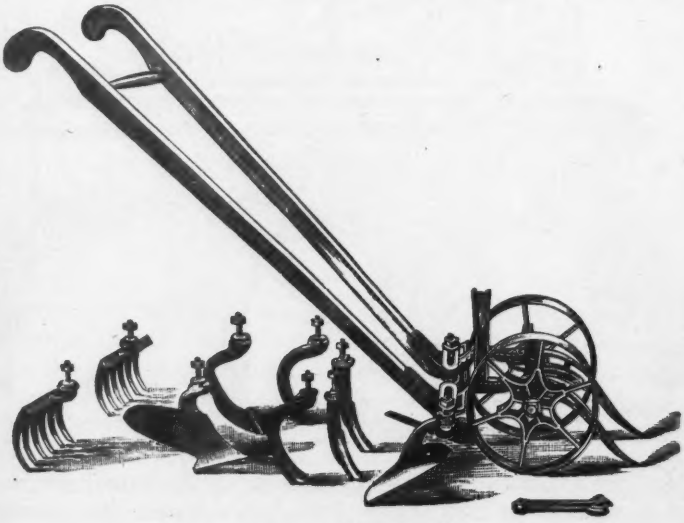

FIG. 10.—Cultivator for beets.

In growing beets with irrigation a cultivator which will prepare the furrow for conducting the water over the field is important. Such a device is shown in figure 11. In this implement the plow shown in the

rear of the cultivator teeth forms the required furrow and can be set at any required depth.

In the cultivation of large areas an implement adapted to four rows of beets is desirable. Such an implement, however, can not be

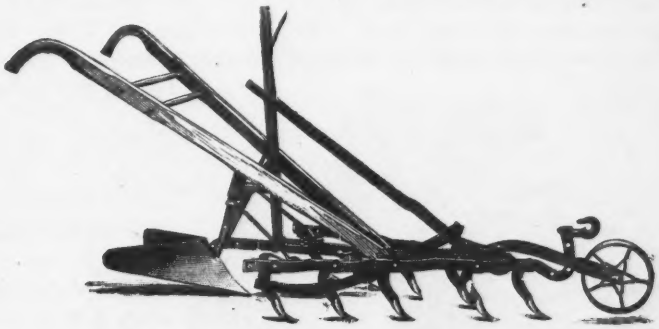

FIG. 11.—Beet cultivator for irrigated lands.

advantageously used, except in those cases where the beets have been sown with an implement planting four rows at a time. The cultivator shown in figure 12 is suitable for use on fields which have been planted

FIG. 12.—Four-row beet cultivator.

with the seeder shown in figure 7. Different kinds of devices for cultivation can be easily attached so that the implement can be used as a plow, a cultivator, or a harrow.

BUNCHING AND THINNING.

When the beets show three or four leaves, they should be bunched and thinned. The bunching is best accomplished with a short-handled hoe. One stroke of this implement takes out all the beets in the row except small bunches from 8 to 10 inches apart, depending on the width between the rows and other circumstances. From these bunches should be removed by hand all the plants but one, the largest and healthiest. Great care should be exercised in this work, and by careful selection all of the inferior plants will be removed. On the proper thinning, the tonnage largely depends. This does not mean that less space should be left between the plants. If the rows be 18 to 24 inches apart, the space between plants can vary from 8 to 10 inches, depending on the nature of the soil. When thinning, it is a good plan to give the ground a thorough hand hoeing. This can be done at a little extra expense and will pay for itself in the long run. If the thinning is put off too long, the crop will suffer.

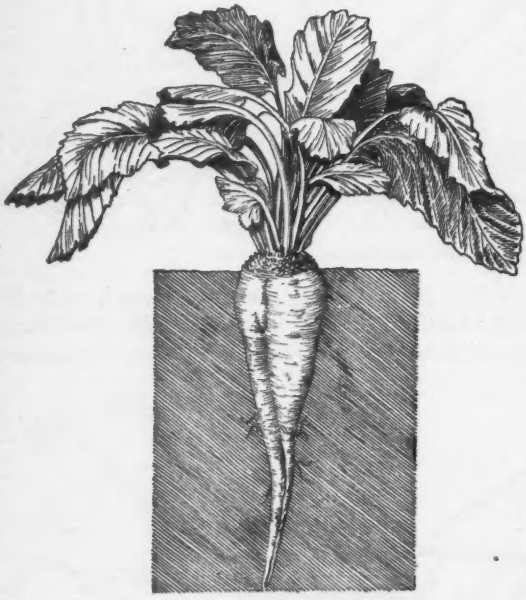

FIG. 13.—Correct position of a mature beet in the soil.

POSITION OF THE BEET IN THE SOIL.

It is important not only that a sugar beet should be of proper size and shape, but also that it be grown in such a manner as to secure the protection of the soil for all of its parts except the top with foliage. The proper position for a beet to occupy in the soil at the end of growth is shown in figure 13. This position can only be secured for the beet by growing it in a soil sufficiently pervious to permit of penetration by the taproot to a great depth. It is for this reason that subsoiling in the preparation of a field for the growth of sugar beets is of such great importance. If the beet, in its growth, should meet a practically

impervious subsoil at the depth of 8 or 10 inches, the taproot will be deflected from its natural course, lateral roots will be developed, the beet will become disfigured and distorted in shape, and the upper portion of it will be pushed out of the ground. Experience has shown that the content of sugar in that portion of a beet which is pushed above the soil is very greatly diminished.

HARVESTING AND DELIVERY OF BEETS.

The time for harvesting varies in different localities. In southern California the beets planted in December are ready for harvesting in the latter part of June or the first of July. In general it may be said that beets planted the first week in May will be ready for harvesting

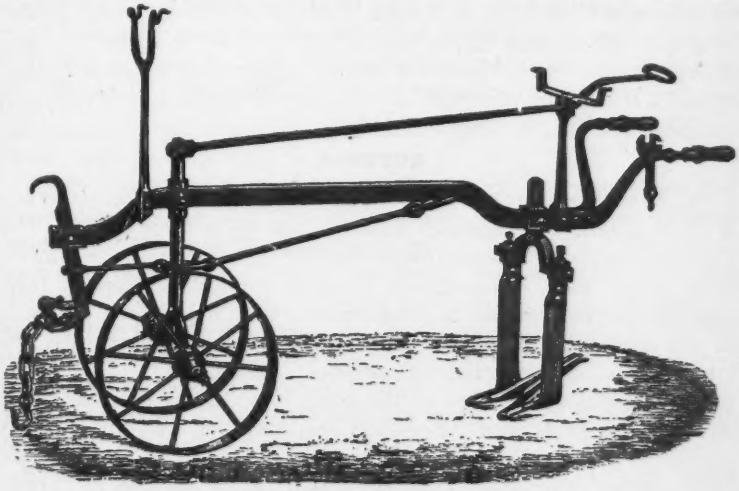

FIG. 14.—One type of beet harvester.

about the 1st of October. Harvesting should be postponed to as late a date as possible, provided the beets are in no danger of a second growth and are not exposed to a freezing temperature. The leaves of the ripened beet change from a rich to a yellowish green, droop and lie close to the earth, and many of them die.

REMOVING BEETS FROM THE GROUND.

The harvesting is easily accomplished by first loosening the beets in the soil and then removing them by hand. For loosening the beets a common turning plow is often used. The edge of the share cuts off the tap roots at the proper depth and the beets are lifted and thrown over by the moldboard. Better adapted to this work, however, are plows which have been specially constructed for beet harvesting. In many localities beets are harvested with an implement such as that

shown in figure 14. It can be used very successfully where rows are perfectly straight and the beets of uniform size. The lifting part of the apparatus runs deep enough in the soil to catch the beet below its middle part. As the "digger" is drawn forward, the beets are caught between its two prongs, which are nearer together in the rear and slope upward; as a result the beets are lifted and the tap roots broken. After the harvester has passed, the beets are lifted out of the ground by means of the leaves.

Several more or less complicated devices have been invented which are designed not only to lift the beets but to cut off the tops and shake off the adhering dirt. Some ambitious inventors have attempted the construction of a harvester which will not only dig, top, and clean the beets, but load them into a wagon. Such a harvester is much to be desired; but while some of these inventions have worked fairly well under favorable conditions, it must be said that none has yet proved satisfactory under all conditions. Hence the use of such harvesters has been very limited.

TOPPING.

The next operation consists in removing from each beet the top or neck bearing the leaves. This is done by a large knife. The object of removing this portion of the beet is to prevent the mineral salts, which have accumulated in large quantities therein, from entering the factory, as they exercise a very deleterious influence on the crystallization of the sugar. The tops and leaves are well fitted for feed or for fertilizing purposes. (See p. 39.)

The removal of the tops of the beets is a tedious process, which in Europe is performed by women and children. In this country sometimes the whole family goes to the beet field and performs the work. More commonly, however, it is done by laborers of various nationalities, who are brought in by the factory and with whom the farmer contracts to do this work as well as the hand work of growing the crop.

The topping of the beets can be a source of great waste for the farmer, as too much may be taken off and the tonnage decreased. Constant supervision is necessary in this work. Several attempts have been made to construct a mechanical device by which the beets can be topped, thus saving a large expense, and perhaps a successful device of this kind may some day be invented. So far as is known at the present time, however, this process has not been successfully accomplished by machinery, and the topping must still be done by hand.

When the beets are topped they are thrown into piles, and the leaves are thrown over them as a protection from the sun or frost until they can be delivered to the factory.

DELIVERING BEETS TO THE FACTORY.

After they are harvested and thrown in piles in the field the beets are usually loaded into wagons and hauled directly to the factory or to a railway station for shipment to the factory. Ordinary farm wagons are often used for this purpose; but wagons specially designed for this work are more satisfactory, and hence are widely used. The bottom and sides of the wagon bed are made of slats with one-half to 1 inch spaces between. As the beets are hauled the shaking and rubbing of the beets tends to free them of adhering soil, which falls out through the cracks. The ends of the wagon bed are stationary and the sides are hinged so as to drop down. These wagons will hold from 3 to 6 tons. A net of rope having from 2 to 3 inch mesh is spread in the wagon first, and on this the beets are thrown. On arrival at the factory the side next the bin is lowered and the projecting net on the other side is fastened to a tackle and raised by power. In this way the load is dumped quickly and with little labor. Sometimes nets are used as a means of lifting beets from ordinary farm wagons.

Where the beets are shipped by rail a special dumping apparatus is installed at the shipping point. The usual form of railroad dump is a high platform approached by a long incline. The loaded wagon is drawn up, the team is unhitched, the wagon locked on the platform, the side dropped, and the platform tipped by machinery. In this way the load is dumped. With another style of dump the wagon is not driven up on a platform, but is left on the ground, the wagon bed being lifted to a height and then dumped.

In cases where there is no railroad dump, a car is placed on a siding and the beets are shoveled into it.

When delivering to the factory, the farmer need not go home with an empty wagon; he can collect manure to be used in fertilizing his fields or can obtain a load of pulp for feed. Most factories, in their contracts with farmers, stipulate that a certain percentage of the weight of the beets delivered can be taken back in the form of pulp. This is a valuable cattle food and the farmer should not miss the opportunity to use it.

TARING.

In shoveling the beets into wagons for delivery to the factory, a certain amount of extraneous matter, such as stems, tops, and clods of dirt, are also thrown in; moreover, certain soils cling to the beets more than others, especially after wet weather. Some deduction must be made from the weight of the load delivered to account for this. Again, the topping may be very poor, not enough being removed, so that there is a loss to the factory, which should be considered. A sample is taken when the load is dumped into the bins

at the factory, the actual percentage of tare is determined, and this figure is applied to the whole load. From the nature of the case, different loads may have a varying percentage of tare, and this point is a constant source of friction between the growers of beets and the factory. But usually it is stipulated in the contract made by the factory with the farmers that the latter may appoint a man to oversee this step in the process.

SILOING SUGAR BEETS.

When beets are to be preserved for manufacture during the winter months or for the production of seed, they must be carefully protected from the deteriorating effect of freezing and thawing. The simplest and the easiest method is to place them in piles and cover them with earth, not too deeply, for if they become too warm in the silo they rapidly lose in sugar content. When first siloed, they should be covered with only a slight layer of earth; as the cold of winter becomes more intense this covering can be increased. In some localities only a slight covering of straw is necessary to protect the beets, as, for instance, in California. In other localities, such as in Michigan and Wisconsin, it is probable that the beets have to be covered to the depth of 6 inches, and even more, to protect them from frost.

It is most important not to put too many beets in one pile, certainly not over 5 tons. If, however, the silo is made in the form of a rick, no such limitation is necessary. There must be an opening in the top to allow ventilation. In case of a rick there may be several. The silo should be placed on the highest point of land available to provide for proper drainage in case of heavy rains or melting snow. The beets should be siloed on the same day that they are removed from the ground.

The object of siloing, in case of beets for seed, is to prevent them from freezing, and greater care should be used in making the silos. In the case of factory beets, the purpose of siloing is not entirely to prevent freezing, for in the frozen state the beets do not deteriorate to any extent; but it is to keep them fresh and prevent their withering or drying out. Freezing and thawing, however, must be avoided, as beets that freeze and thaw a number of times lose a greater part of their sugar by inversion and decomposition.

It is becoming customary in this country for the sugar companies to ask the farmers to silo part of their beets when the total crop can not be worked up before winter sets in. To repay the farmer for this extra handling they are given a sum varying from 20 cents to 50 cents a ton extra. A few factories situated in the cooler regions where siloing must be practiced agree to take all of the beets of the farmer before frost comes and silo them, but this is not the

general practice. In California very little siloing has to be done, and then only by using the leaves as a covering.

COST AND PROFITS OF GROWING SUGAR BEETS.

The cost of growing an acre of beets depends on so many varying factors as to render it impossible to give an estimate which is reliable for every locality. The differences in rent of land, cost of labor, methods of culture, etc., require that any estimate which may be given should be revised for almost every series of conditions. The following estimate of the cost per acre, made several years ago when wages were somewhat lower than at present, is based on a yield of 12 tons per acre, except in Utah, where the yield was placed at 15 tons.

An assumed yield per acre is requisite in estimating the cost of harvesting, etc., since a part of the cultivation and the harvesting are often contracted at a certain price per ton of beets. The figures given below are from actual averages or from estimates by experienced men.

Estimated cost per acre of sugar-beet culture.

Items.	California.	Utah.	Nebraska.	Michigan.
Clearing the land			$1.00 to $1.50	$2.25
Plowing and harrowing	$5.37	$3.50	2.50 to 3.00	
Seed and seeding	1.80	2.75	3.25 to 3.85	2.50
Bunching and thinning	14.40	4.00	7.00	7.00
Hoeing		4.00	2.00 to 4.00	4.00
Cultivating		2.00	1.50 to 1.60	1.50
Other expenses		[a] 1.50		
Harvesting and delivering	[b] 1.50	[c] 15.00	11.00 to 13.20	17.20
Total	23.07	32.75	28.25 to 34.15	34.45
Cost of siloing when necessary			2.50 to 8.00	

[a] Cost of irrigation. [b] Exclusive of delivery. [c] Based on a yield of 15 tons per acre.

In the above estimate was included the cost of the best culture, but nothing for rent of land or a reasonable application of fertilizers. It is probable that the actual cost to our farmers for the first few years of the beet industry did not exceed $25 to $35 per acre and in many instances fell below these figures.

It is reasonably certain, accidents of season aside, that a net profit of from $8 to $15 per acre may be expected from the proper culture of the sugar beet in localities near a factory when all the conditions of the best methods of culture are fulfilled.

For comparison with the above estimate there are given in the following table the actual figures submitted by a Colorado farmer, as published in The American Sugar Industry and Beet Sugar Gazette of June 20, 1907, and also those given by a Wisconsin farmer and a Washington farmer in the same journal for April, 1908.

Reported cost of sugar-beet culture in three actual cases, and the net returns.

Items.	Colorado.	Wisconsin.	Washington.
Number of acres planted	5	11	11
Plowing, harrowing, leveling	$8.75	$34.85	$24.00
Seed	$12.30	$39.00	$26.70
Drilling	$2.25	$6.40	$4.00
Thinning	$22.75	$60.00	$66.00
Hoeing	$10.25		$30.50
Cultivating and ditching	$9.00	$27.50	$17.50
Irrigating	$3.50	.....	.....
Total cost	$71.05	$167.75	$168.70
Average cost per acre	$14.21	$15.25	$15.34
Cost of harvesting and delivery	.....	$218.00	$133.15
Total average cost per acre	$27.00	$35.07	$27.44
Number of tons of beets harvested	.....	135	115
Amount received for beets	.....	$695.00	$607.00
Average receipts per acre	.....	$63.18	$55.18
Net returns per acre	.....	$28.11	$27.74

In none of these estimates have the rent of the land or interest on capital been considered. It is not wise to underestimate the actual cost of growing the beets, for this will lead the farmer to expect large profits, which often in practice give way to actual deficits.

VALUATION OF BEETS AT THE FACTORY.

In the purchase of beets for sugar making the factories offer the growers either a "flat rate" or a "sliding scale." In case the former system is adopted, the factory offers a uniform price of $4.50 or $5 per ton for all beets which reach or exceed a certain minimum standard of quality, as, for instance, a sugar content of 12 or 14 per cent with a purity of 80. In case beets which fall below this standard are offered, the factory may make a reduction in the price or refuse the beets, but no extra price is paid for beets which exceed the standard requirements. If the "sliding scale" is adopted, the factory offers a minimum price of say $4 or $4.25 for beets which reach a minimum standard of quality, as, for instance, 12 per cent of sugar with a purity of 80, and makes an extra allowance per ton of 25 to 35 cents for each per cent of sugar in excess of the established minimum. Under this system beets of extra fine quality may bring $5.50 per ton or even more. Some factories buy all their beets at a flat rate, others buy only according to a sliding scale, while many offer the farmers their choice between the two systems.

In determining the quality of the beets a sample is taken from each load delivered. The percentage of sugar is determined either directly from the beet or from the expressed juice. If from the juice (which is the usual method), the percentage of sugar in the beet is calculated from that in the juice.

According to a United States Census report on the manufacture of beet sugar in 1905, the average prices paid for beets were as follows:

Prices per ton paid for beets in 1900 and 1905 compared.

State.	1905.	1900.
	Dollars.	*Dollars.*
Colorado	5.28	.....
Michigan	5.52	4.38
California	4.72	4.47
Wisconsin	5.36	.....
All other States	5.19	4.26
Average for the United States	5.22	4.39

A comparison of these figures shows that there was a large increase in the price of beets during this five-year period.

BEET-SEED PROBLEMS.

PRODUCTION OF SEED.

The production of seed is one of the most important operations connected with the sugar-beet industry. On the care and skill which are displayed in this process depend the improvement and maintenance of the sugar-producing qualities of the beet. It is, however, an industry in itself and only the result is of practical interest to the average farmer. There are many different methods employed for producing seed which will grow the richest sugar beets, but there will be given here only a general outline of the principles which underlie the process. The beets which are to be preserved for seed are called "mothers" and are selected at the time of harvesting from specially grown beets or from fields of beets which have shown particularly good qualities on analysis. The size of the roots selected for mothers is about the average for the best sugar beets, viz, from 20 to 24 ounces. Smaller beets than these might show a higher content of sugar, but it is not wise to produce a race of small beets. The weight of the mothers having been decided upon, the beets are next selected for their shape and external appearance. Those regular in shape and smooth in external form are to be preferred.

The beets to be preserved for mothers are harvested with the greatest care to avoid injury. The top is not cut away, but the leaves are removed by cutting off the stems without injuring the top of the beet.

They should be siloed in such a way as to protect the beets entirely from frost and yet prevent their growth in the silo until the spring. The beets are removed from the silo at an early date in the spring and are immediately subjected to analysis. The final selection depends upon actually determining the density of the juice and its content of sugar. For this purpose a cylindrical piece of the beet is removed

by an appropriate instrument cutting diagonally through the center of the root. This piece may weigh one-half ounce or even more, and its removal does not injure the beet for seed-bearing purposes. The juice is expressed from this piece and its specific gravity determined, as well as the percentage of sugar in the juice. From the specific gravity the amount of solid matter in the juice can be calculated. The percentage of sugar is determined by means of the polariscope.

From these data the quality of the beet is ascertained and the question as to its use as a mother for seed is determined. An important figure in this work is the ratio of sugar to total solids in the beet; that is, the sugar divided by the total solids, the quotient being multiplied by 100. This figure is spoken of as the "coefficient of purity."

The procedure for selecting beets where seed is produced on a commercial scale is in brief as follows: A standard is set for sugar content and also for purity. The beets are analyzed separately and are divided into two classes, namely, those in which either the content of sugar or the purity falls below the fixed figure, and, second, those in which these two numbers equal or exceed the fixed figures. It is sometimes customary to divide the latter class into two portions, viz, those roots in which the numbers equal or slightly exceed the standard, and, second, those which show exceptional richness. It is also customary to number each beet, and the number, which is cut into the skin of the beet, will remain legible even after the seed has ripened. Some of the producers of sugar-beet seed preserve the product of seed from each beet by itself, and do not use it to inaugurate the production of seed for commerce until it has received an additional year's trial.

Many seed producers determine the percentage of sugar in the beet by a direct analysis of a pulped sample and base the selection of the mothers on the number so obtained, without regard to the coefficient of purity, as it has been proven in Germany that a beet of a certain sugar content will under most circumstances have a certain purity.

By careful selection of mother beets and scientific culture the sugar beet has been raised to its present high standard of excellence, and is only maintained at this standard by constant supervision, such as has been indicated.

DOMESTIC PRODUCTION OF BEET SEED.

The commercial production of beet seed of pure pedigree and high grade has not been practiced to any great extent in this country. Beet seed has been grown for a number of years in the State of Washington and also in Utah. The latter State consumes its own crop, while the seed from Washington has been used in all the beet-growing States. In 1904 the Department of Agriculture distributed 13,962 pounds of American-grown sugar-beet seed, the greater part coming

from Washington. This seed went to farmers growing beets for factories, and therefore was tested in direct comparison with the factory seed which is practically always imported. It was tested on 153 farms, representing thirteen different States, 564 acres being planted. The results gave an average yield for Washington-grown seed of 10.72 tons per acre, against 9.92 tons harvested from an equal area raised from imported seed.

To grow sugar-beet seed commercially certain conditions must exist which are not always applicable to experimental work. It is necessary not only that seed of high quality be grown, but also that it be grown economically and that there be reasonable certainty of a crop. Climatic conditions, such as the probability of severe rainfall at the time of harvesting, play an important part in selecting a location for a beet-seed farm. The prevalence of insects and other pests must also be considered.

COMPARATIVE VALUE OF DOMESTIC AND FOREIGN SEED.

Numerous comparisons of home-grown and imported beet seed have been made. The plants from the native-grown seed seem to have a higher vitality and to be better suited to the climatic conditions of the locality than those grown from imported seeds. They show during the growing season a more abundant foliage and a better development of roots. This higher vitality and quality of the beets grown from domestic seed illustrate in a forcible degree the advisability of the production of our beet seed at home. Even granting that seeds produced in foreign countries have the same high qualities, it must be admitted that their vitality is in danger of being very much diminished during shipment to this country. The moist air in the holds of ships in which they are transported often produces moldiness and incipient germination, which tend to diminish their value greatly. In 1904 American-grown seed yielded 10.72 tons of beets per acre with a sugar content of 15.41 per cent, while imported seed averaged 9.92 tons with 15.26 per cent of sugar, the excess of sugar from the use of American-grown seed being from 300 to 350 pounds per acre. In 1905 American-grown seed yielded 14.32 tons of beets per acre with 14.9 per cent of sugar, while imported seed averaged 12.14 tons with 15.1 per cent of sugar, an excess of more than 600 pounds of sugar per acre of beets. In 1905 the averages were taken from 278 acres. These data should be carefully studied by all those who are interested in the production of beet sugar in this country. At present there is one grower of beet seed on a large commercial scale, and it is certain that it will not be long before there will be a demand for the establishment in this country of more plantations devoted exclusively to the production of beet seed on the most approved scientific principles.

The quantity of seed required to plant an acre is about 15 pounds. The approximate number of acres planted to beets in this country during the season of 1907 was 400,000, requiring 6,000,000 pounds of seed. More than 6,500,000 pounds of seed were required for the crop of 1908. It is evident that there is already an opportunity for the active operation of large plantations devoted exclusively to the production of beet seed for domestic use.

Another point to be considered is that by the importation of foreign seeds there is danger of introducing those diseases of beets which have occasioned such ravages in Europe.

SINGLE-GERM BEET SEED.

The average beet-seed ball contains from 1 to 7 germs or seeds, each capable under certain conditions of producing a plant. In practice some seed balls will produce as high as seven plants, while others will only produce one. The Bureau of Plant Industry of the Department of Agriculture has undertaken the development of a strain of sugar beets bearing single-germ seed balls, and the results of that work up to 1905 have been published in a bulletin of that Bureau (No. 73). By careful selection, plants bearing 50 per cent of single-germ seeds have been produced. It is confidently expected that in time a plant bearing only single-germ seeds will be produced. The economy in the use of such seed is evident, as, when planted in a row, the thinning can be done by means of a hoe, thus doing away with hand thinning. This work was undertaken in 1902, and up to the present time is still in an experimental stage, none of this seed being available for distribution.

DISEASES AND INSECTS AFFECTING THE SUGAR BEET.

There are three diseases of the beet which prove especially destructive: One is the "leaf spot" due to a fungus (*Cercospora beticola*), in which the leaves are covered with brown spots and die, forcing the beet to throw out new leaves at the expense of the sugar content and growth of the root. This has been successfully combated on a small scale by spraying with Bordeaux mixture, but whether this can be done economically on a commercial scale is still under investigation. The second disease, "root rot," likewise due to a fungus (Rhizoctonia), in which the roots finally rot off, seems to be increasing. If attended to in time, it can be checked by the use of air-slaked lime. The lime is sprinkled broadcast over the infected area and thoroughly hoed into the soil. The third disease, known as "curly top," causes the leaves to curl up; the beet does not develop, but finally dies. No satisfactory means of combating this disease has

so far been devised, but a report on the subject has been issued by the Bureau of Plant Industry [a] of the Department of Agriculture.

A number of other diseases, including "crown rot" and "damping off," have been studied, but they are confined to small particular areas and have not wrought the damage that follows the three especially mentioned.

Many species of insects use beets as food. Not more than about 50 species, however, are classed as noticeably destructive to the crop. Many of these have received extended notice in publications of the Bureau of Entomology [b] of the Department of Agriculture. From these reports the farmer can learn what has been done along this line and obtain suggestions as to the means of fighting the pests.

The beet growers should send specimens of insects injurious to their crops direct to the Bureau of Entomology for specific identification and advice as to remedies.

THE MANUFACTURE OF SUGAR.

THE FACTORY PROCESS.

The process of making sugar from the sugar beet is only of secondary interest to the farmer, and will be treated as briefly as possible, giving merely an intelligent general idea of the methods followed. The beets are stored in bins which narrow down to a flume covered by small boards. By removing the boards, one at a time, the beets are fed into the flume, where a swift running stream of water carries them to a wheel or screw that lifts them to a washing tank. This is provided with an apparatus for keeping the beets in motion and transferring them toward the end from which the fresh water enters. In this process the whole of the adhering soil, together with any sand and pebbles, is completely removed. By a suitable elevator the beets are next taken to a point above the diffusion battery, where they pass into automatic scales, which dump them when a certain weight has been received. From this they are dropped into a slicing apparatus, by which they are cut into thin pieces, called "cossettes," of greater or less length, and of such a shape that when placed in the cells of the battery they will not lie so closely together as to prevent the circulation of the diffusion liquors. When the cell is full of the sliced beets it is closed and the hot juices from the cell last filled are admitted and allowed to remain in contact with the cuttings for a few minutes. From 10 to 12 cells are thus kept in use. While one is filling another is emptying. The fresh hot water is

[a] U. S. Dept. Agr., Bureau of Plant Industry, Bul. 122.

[b] A Brief Account of the Principal Insect Enemies of the Sugar Beet, Bul. 43, Bur. of Ent., U. S. Dept. of Agr. Reference is also made to insects of this class in Buls. 23, 29, 33, 54, and 66 of the same series.

always admitted to the cell next to be emptied and passes in succession through all the cells under pressure, until it reaches the one last filled. From this cell a quantity of juice is drawn off each time and sent to the carbonatation tanks for purification. With the drawing

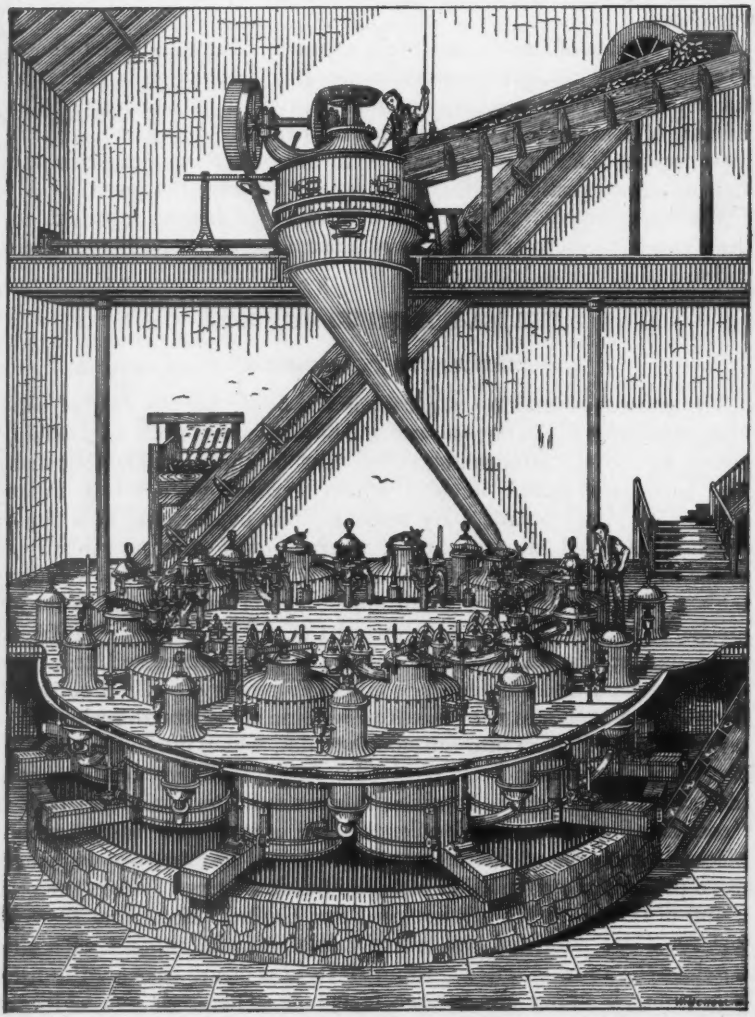

FIG. 15.—Diffusion battery.

off of a certain quantity of the juice, one cell of exhausted beet pulp, the last one in the circuit, is dumped. Figure 15 illustrates in a general way the arrangement of a diffusion battery, but the circular type

there shown is no longer in use, the cells now being arranged in a straight line.

The extracted cuttings are carried by conveyers to a press, where a portion of the water is removed, and they are then "scrolled" out to a silo in suitable condition for use as cattle food. The diffusion juice obtained as above described is conveyed to carbonatation tanks, where it is treated with from 2 to 3 per cent of its weight of lime in the form of a thick milk. The whole is heated and carbonic acid gas (obtained from the limekiln) is pumped into the mixture until a certain alkalinity of the juice is obtained. By this process the impurities in the diffusion juice are to a great extent thrown out and some of the extra lime precipitated also.

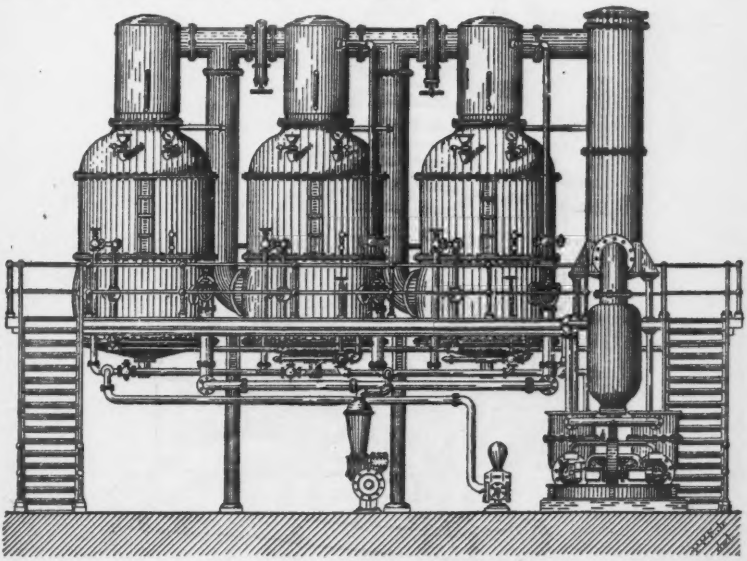

FIG. 16.—Multiple-effect evaporating apparatus.

The slightly alkaline juice is next passed through filter presses, by which the precipitated lime and other solid matters are removed. The juice from these filters then passes to a second set of carbonatation tanks, in which they undergo a treatment similar to that just mentioned, but the quantity of lime added is small as compared with that of the first carbonatation. The refiltered juices from the second carbonatation, usually termed the "saturation," are then sent to tanks, through which the fumes of burning sulphur or sulphur dioxid are passed. This treatment removes more lime and impurities besides lightening the color of the juice. From these tanks the juice goes to another set of filters, generally composed of bags, and from there to storage tanks for the multiple-effect evaporators.

The multiple-effect evaporating apparatus (fig. 16) consists of a series of pans connected in such a manner as to secure a progressively higher vacuum. The thin juices enter the first pan, where they may be evaporated, either under slight pressure or in a vacuum. The steam with which this evaporation is effected is usually the waste coming from the engines and pumps of the factory.

The vapors generated in the first pan enter the heating pipes of the second one, and are thus utilized in evaporating the somewhat concentrated sirup which is drawn off from the first pan into the second one, where the vacuum is higher, being represented by a column of mercury of from 12 to 15 inches in height. The vapors which are produced in

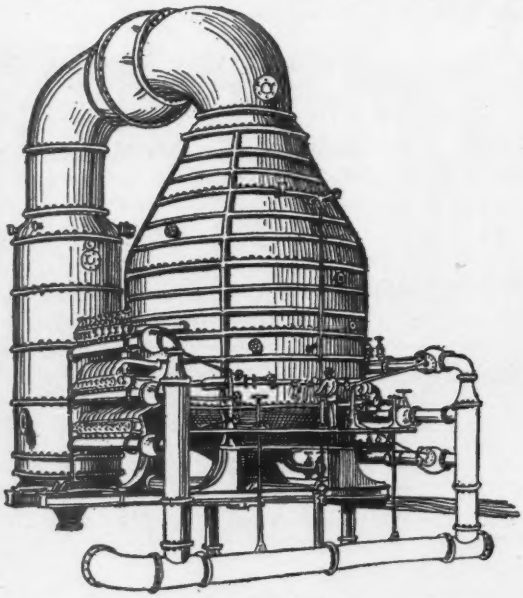

FIG. 17.—Vacuum strike pan.

the second pan are in like manner conveyed to the heating pipes of a third apparatus, where the still more concentrated sirups from the second pan are conducted and evaporated at the highest vacuum obtainable in such apparatus, usually from 26 to 28 inches of mercury. Usually a fourth pan is employed, but the arrangement is fully illustrated by the above example. It is easy to see by the arrangement above noted that the evaporation of the thin diffusion juices to a heavy sirup is accomplished with the greatest economy, direct steam being admitted only into the first pan, and the rest of the operation being accomplished by the steam generated in the evaporation of the liquors. The thickened juice from the last effect of the multiple

evaporator is sent to tanks where it is again treated with lime, phosphoric acid, and soda to remove impurities, and also with sulphur dioxid to lighten the color. From here it passes to bag filters and then into storage tanks. This juice is converted into sugar in the following manner:

A portion of the sirup is placed in an evaporating apparatus called the strike pan. This apparatus is very large, usually a cylindrical vessel with a conical bottom, and is provided with a series of coils, one above the other, to which the steam can be admitted at will. The admission of steam is always so regulated that it is not allowed to enter any of the coils above the surface of the liquid in the pan. The

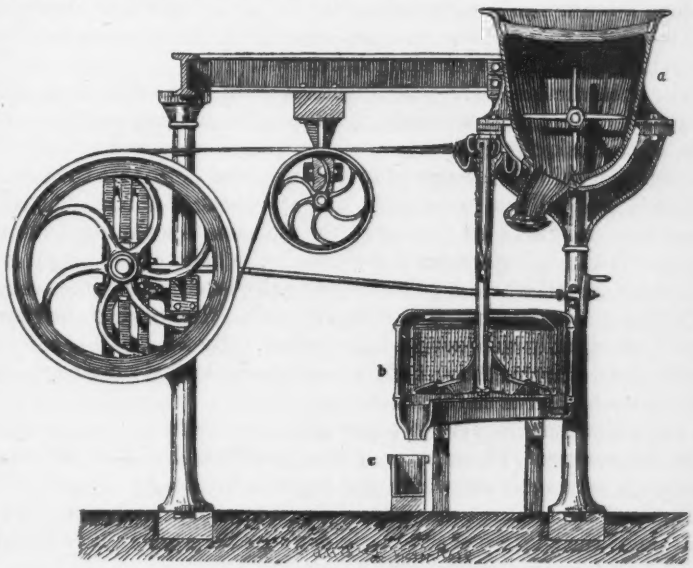

FIG. 18.—Centrifugal apparatus: *a* holder for massecuite; *b* centrifugal basket with fine wire lining *c* molasses trough.

portion of sirup first introduced is evaporated until it reaches a point of consistency which will permit of the formation of crystals, i. e., supersaturation. In this condition, if a portion of fresh sirup be introduced the whole mass in the pan becomes charged with exceedingly fine crystals of sugar.

By careful manipulation and the introduction of new quantities of sirup from time to time these crystals are made to grow. As the pan becomes full successive coils of the steam pipes are brought into use, so that the boiling surface of the pan is gradually increased in proportion to the volume of its contents. In the course of a few hours the skilled sugar boiler will find that the pan is full and that the crystals

have grown to the proper size. The charge in the vacuum pan at this stage is extremely heavy, consisting of a dense mass of sugar crystals mixed with a quantity of molasses which varies in amount with the purity of the juices from which the sugar is made. This product is termed massecuite. The illustration (fig. 17) shows the vacuum pan. In boiling sugar in a vacuum pan, if the highest possible yield is desired and no objection arises to the formation of soft crystals, a very high vacuum, equivalent to 29 inches of mercury at the sea level, is employed. At this vacuum the sirups boil at a temperature of from 112° to 120° F. If harder crystals, giving a somewhat less yield are desired, as in the case of making granulated sugars, a lower vacuum, namely, from 24 to 26 inches, is employed.

The massecuite is then dropped directly to the mixer, where it is stored for charging the centrifugals below it.

The construction of the centrifugal apparatus and mixer is shown in figure 18. The centrifugal basket is suspended and run by the spindle. The whole basket is incased in an armor-plate jacket and is lined with fine wire gauze. The charge of massecuite is let down into the basket, which is revolved by means of the belt at a speed of about 1,200 revolutions per minute. At this speed the molasses is separated from the sugar crystals, being thrown out through the holes of the screen onto the outer jacket, where it collects and finally runs through the trough, provided for the purpose, to the storage tank. The color of the charge is now changed from brown to light yellow. By a sprinkling can or a small spray of water the rest of the molasses in the fast running centrifugal is washed off of the crystals.

From the centrifugals the sugar passes by belts and conveyers to bins for storage. From these it is carefully and slowly fed into a heated revolving drum where the sugar is dried and the masses of individual crystals are broken up. This is termed granulation. From this point the sugar passes to weighing machines where it is barreled or sacked for commerce.

The resulting molasses is still rich in sugar and is brought back to the vacuum pan where it is boiled to a massecuite which is placed in large double-jacketed tanks having a revolving worm. The double jacket is filled with heated water and the massecuite is allowed to stay in the tank for a number of days, being mixed by the revolving arm. The temperature is allowed to fall slowly and by this means more crystals of sugar are formed. When no more of the sugar will crystallize, the tank or "crystallizer" is emptied into another set of centrifugals and the sugar is spun off. This crop is generally very dark in color and washing does not lighten it to a white sugar. It is known

as second sugar and is melted in water and boiled up with the juice from the evaporator in the vacuum pan to make white sugar. In its raw state it is not the same as the yellow sugar of commerce, being generally salty and disagreeable in taste. The resultant molasses is sometimes boiled for a third crop of sugar, but generally it is sent to storage or is used in the osmose or Steffens process for removing more sugar from the molasses.

In the osmose process a stream of heated, diluted molasses is run in a suitable press in the opposite direction to a stream of hot water, a sheet of parchment paper separating the two streams. By this means a greater portion of the salts passes through the membrane and enters the water which flows away. The sirup is made richer, and by boiling in the evaporator and in the pan a massecuite is formed that is stored in crystallizers, and finally the sugar is spun off. The remaining molasses is sometimes reosmosed, but generally it is sold to be mixed with pulp or grain for cattle food or is used for alcohol making.

In the Steffens process the molasses is diluted and cooled to a low temperature, which is kept constant while finely powdered fresh lime is added slowly. In this way a saccharate of lime is formed which is insoluble in the liquid, and by passing the whole material through filter presses it is separated. The cake from the presses is diluted with water and takes the place of the milk of lime used in the carbonation. When this process is employed there is no residue molasses; the only waste is the strongly alkaline water containing the salts of the molasses which have been separated from the saccharate of lime. This water is rich in potash salts and could be used as a fertilizer.

The beet-sugar factories of this country sell only the white granulated sugar; none of them produce raw sugar and turn it over to the refineries to be passed over bone black and made into white sugar, as is the custom in Europe.

COST OF MANUFACTURE.

The cost of manufacture depends on as many factors as that of beet growing. Chief among these are transportation, fuel, weather, and labor. Perhaps the most important of these factors is the price of fuel. In some localities coal can be had for $1.25 per ton; in others the cost may reach as high as $10 per ton.

The manufacture of beet sugar is conducted without governmental supervision in this country, and any exact account of its cost is inaccessible. To show what it may be, when a wide experience and the best management are brought to bear upon the work, the mean cost of manufacture in 113 German factories is given.

Mean capital invested in each factory		$193,400.00
Total receipts for sugar, molasses, and pulp per ton of beets		11.10
Mean cost of beets per ton of 2,204.62 pounds	$4.90	
Salaries per ton of beets	.26	
Labor per ton of beets	.73	
Interest on investment per ton of beets	.36	
Coal per ton of beets	.63	
Miscellaneous expenses per ton of beets	.96	
Total expense of manufacture per ton		7.84
Profit per ton of beets		3.26

The mean net profit for each factory was $34,240. The price paid for beets, however, is in most cases fictitious, the beet growers owning the factory and preferring to share in the general profits rather than to charge a high price for the beets. First-class beets rarely sell for less than $5 per ton. The Western Beet Sugar Company, of Watsonville, Cal., stated that in its first campaign, 1888–89, the cost of manufacture amounted to $80.80 per ton of sugar. At the present time it appears that with the best machinery, rich beets, and most economical processes beet sugar can be made in this country at a cost of less than 4 cents per pound, even when the price of rich beets exceeds $5 a ton.

COST AND CAPACITY OF FACTORIES.

The cost of building a first-class beet-sugar factory is much greater than is commonly supposed. Roughly speaking, for every ton of daily capacity, the plant costs $1,000; that is, a 500-ton plant would cost $500,000 and a 1,000-ton factory would cost $1,000,000. It has been demonstrated in the United States that a beet-sugar mill, in order to work economically, must have a capacity to work 500 tons of beets daily, and that one having a capacity of much more than 1,200 or 1,500 tons a day is unwieldy. The largest factory in the United States can handle 3,000 tons a day. In Germany there are a few small factories of 200 and 300 tons capacity, but the tendency of late has been to increase the size. In the early days of the beet-sugar industry in this country, Europe was called on to furnish all machinery. Now, very little is imported, and, in fact, some of the foreign factories are using American-made machinery.

COOPERATIVE FACTORIES.

It is seen from the foregoing paragraph that the farmer can have no reasonable hope of successfully establishing a home beet-sugar factory. It is not just, however, that he should be deprived of any cooperation in the process of manufacture or a reasonable share of the profits arising therefrom. The methods which have been practiced in Europe for securing these results may eventually come into use in this country. The cooperative sugar factory, in which the farmers growing the

beets hold a part or a majority of the stock, realizes the desired end. The growers of beets holding shares in the factory have a greater interest in its prosperity and try to grow better crops and to secure in every way a higher yield. The cooperative factory renders impossible those disagreements between factory and agriculture which do so much to retard the progress of the industry and to embitter the farmers against the factory. To show the extent of the participation of shareholders in factories in the growing of beets in Germany, it may be stated that of the 11,672,816 metric tons of beets delivered to the German factories in 1895–96, 2,689,004 tons were grown by shareholders. As long as the proprietors of the factory and the farmers growing the beets are satisfied with the contracts which they make, there is no urgent necessity for the establishment of cooperative enterprises. When the number of beet-sugar factories in this country, however, begins to reach the hundreds, favorable opportunities for cooperative establishments will be presented.

USES OF BY-PRODUCTS.

The by-products from beet culture on the farm are the tops and leaves, which are commonly used for feeding cattle. Some farmers, however, turn them under as a fertilizer. When used as a feed, the beet tops can be eaten by the cattle on the field where they have been grown. If they are fed in stalls, the manure should be returned to the field.

The by-products of the factory consist of pulp, lime cake, and molasses. The pulp is a valuable cattle food and the farmer should contract with the sugar company to obtain his share of it. It can be stored in siloes, if well drained, and be fed fresh or in a fermented condition. The value of the pulp for feeding purposes is variously estimated at from one-fifth to one-third the value of the beets. Its sugar content is not sufficient to make it of any value as a source for alcohol manufacture. Lime cake in most factories is washed out with water to the sewer. In others it is wheeled out and dumped in piles and can be used on some lands as a fertilizer, though for this purpose the demand for it is limited. Lately it has been used in cement making. Molasses has a value as a cattle food, but it must not be fed very heavily or scouring of the cattle will result. The best practice is to sprinkle it on the hay, alfalfa, or roughage. Some factories mix the molasses with the pulp and dry the whole, either pressing it into bricks or selling it loose. With the increased installation of the Steffens process of desugarizing molasses, there is not so much molasses resulting from beet-sugar manufacture as was obtained a few years ago. In an economical plant all molasses should go through this process and only that produced at the end of the season be saved. It is a question whether the introduction of denatured alcohol into the

arts, as well as for fuel and light, will not tend to reduce the number of Steffens plants and result in the sale of the molasses for distillation. Beet molasses contains about 50 per cent of sugars capable of fermentation. One gallon weighing about 12 pounds contains approximately 6 pounds of sugar, which will produce about 3 pints of 95 per cent alcohol. In other words, for every 2½ gallons of molasses 1 gallon of alcohol can be made.

STATISTICS OF PRODUCTION AND CONSUMPTION OF SUGAR.

In the data giving the production and consumption of sugar the unit of value commonly employed is the ton. By reason of the fact that the ton in this country expresses a unit of varying magnitude a considerable degree of confusion is often introduced into statistical tables. In the following tables the kind of ton used is specified in each case. The long ton, which is often used in compiling sugar statistics, contains 2,240 pounds. The short ton, namely, 2,000 pounds, is a more convenient unit of expression, and is largely used in the publication of sugar statistical data in this country. The metric ton, which is used on the continent of Europe, is a weight of 1,000 kilograms, equivalent to 2,204.62 pounds.

BEET-SUGAR PLANTS IN THE UNITED STATES.[a]

The following table gives a complete list of beet-sugar plants in the United States, arranged by States, showing the official names of the manufacturing companies and the locations of the factories. It also shows the daily slicing capacity, expressed in tons of beets, for each factory, the combined daily slicing capacity of the factories in each State, and the aggregate capacity of all the factories in the United States.

Beet-sugar companies and factories of the United States.

Manufacturing companies.	Factory locations.	Number of factories.	Daily slicing capacity.
California:			*Tons of beets.*
Alameda Sugar Co.	Alvarado		800
Los Alamitos Sugar Co.	Los Alamitos		700
Spreckels Sugar Co.	Spreckels		3,000
Union Sugar Co.	Betteravia		600
American Beet Sugar Co., main office, 32 Nassau street, New York; Pacific coast office, 604 Mission street, San Francisco.	Chino		900
	Oxnard		2,000
Pacific Sugar Corporation, Los Angeles, Cal.	Visalia		400
Pacific Sugar Construction Co.	Hamilton City		700
Total		8	9,100
Colorado:			
American Beet Sugar Co., 1530 Sixteenth street, Denver, Colo.	Rocky Ford		1,100
	Lamar		600
	Las Animas		700
Holly Sugar Co.	Holly		600
Holly Construction Co.	Swink		1,200
National Sugar Manufacturing Co.	Sugar City		500

[a] From Progress of the Beet-Sugar Industry in the United States, 1907. Report 86, U. S. Dept. of Agr.

Beet-sugar companies and factories of the United States—Continued.

Manufacturing companies.	Factory locations.	Number of factories.	Daily slicing capacity.
Colorado—Continued.			*Tons of beets.*
	Eaton		600
	Greeley		600
	Loveland		1,200
	New Windsor		600
The Great Western Sugar Co., general offices, Sugar Building, Denver, Colo.	Longmont		1,200
	Fort Collins		1,200
	Sterling		600
	Brush		600
	Fort Morgan		600
The Western Sugar and Land Co	Grand Junction		600
Total		16	12,500
Idaho:			
	Idaho Falls		1,200
Utah-Idaho Sugar Co., main office, Salt Lake City, Utah.	Sugar		1,200
	Blackfoot		600
	Nampa		750
Total		4	3,750
Illinois:			
Chas. Pope, Chicago, Ill	Riverdale	1	350
Iowa:			
Iowa Sugar Co	Waverly	1	500
Kansas:			
United States Sugar and Land Co	Garden City	1	850
Michigan:			
	Bay City		600
	Caro		1,200
Michigan Sugar Co., general offices, Saginaw, Mich.	Alma		700
	Carrollton		850
	Sebewaing		600
	Croswell		600
West Bay City Sugar Co	Bay City, West Side		600
Holland Sugar Co	Holland		300
Owosso Sugar Co., main office, Bay City, Mich	Owosso		1,250
	Lansing		600
German-American Sugar Co	Bay City, Station A		650
Mt. Clemens Sugar Co	Mt. Clemens		600
Menominee River Sugar Co	Menominee		1,200
St. Louis Sugar Co	St. Louis		600
The Continental Sugar Co., main office, Cleveland, Ohio.	Blissfield		600
West Michigan Sugar Co	Charlevoix		600
Total		16	11,550
Minnesota:			
Carver County Sugar Co	Chaska	1	600
Montana:			
The Great Western Sugar Co	Billings	1	1,200
Nebraska:			
American Beet Sugar Co	Grand Island	1	350
New York:			
Lyons Beet Sugar Refining Co	Lyons	1	600
Ohio:			
Continental Sugar Co	Fremont	1	400
Oregon:			
Amalgamated Sugar Co	La Grande	1	400
Utah:			
	Logan		600
Amalgamated Sugar Co., office, Ogden, Utah	Ogden		400
Lewiston Sugar Co	Lewiston		600
Utah-Idaho Sugar Co., main office, Salt Lake City, Utah.	Lehi [a]		1,200
	Garland		1,200
Total		5	4,000
Washington:			
Washington State Sugar Co., main office, Spokane, Wash.	Waverly	1	500
Wisconsin:			
Wisconsin Sugar Co., main office, Milwaukee, Wis.	Menomonee Falls		500
Chippewa Sugar Co., main office, Milwaukee Wis.	Chippewa Falls		600
Rock County Sugar Co	Janesville		600
United States Sugar Co	Madison		600
Total		4	2,300
Grand total		63	48,950

[a] Slicing stations at Springville, Spanish Fork, and Provo.

BEET-SUGAR PRODUCTION IN THE UNITED STATES, 1830-1907.

The following table shows the production of beet sugar in the United States from the beginning of the industry to the close of the season of 1907. The data for 1897 and for 1901–1907 are from reports published by the United States Department of Agriculture on Progress of the Beet-Sugar Industry in the United States. Figures for other years are from Willett & Gray. (See Yearbook, U. S. Department of Agriculture, 1907, pp. 687, 688.)

Beet sugar produced in the United States, 1830–1907.[a]

1830	A few hundred pounds	1890	3,459 tons
1831–1837	None	1891	5,356 tons
1838–39	1,300 pounds	1892	12,018 tons
1839–1862	None	1893	19,950 tons
1863–1871	300 to 500 tons per annum	1894	20,092 tons
1872	500 tons	1895	29,220 tons
1873	700 tons	1896	37,536 tons
1874–1877	Under 100 tons per annum	1897	40,398 tons
1878	200 tons	1898	32,471 tons
1879	1,200 tons	1899	72,944 tons
1880	500 tons	1900	76,859 tons
1881–82	Less than 500 tons	1901	164,827 tons
1883	535 tons	1902	194,782 tons
1884	953 tons	1903	214,825 tons
1885	600 tons	1904	216,173 tons
1886	800 tons	1905	279,393 tons
1887	255 tons	1906	431,796 tons
1888	1,861 tons	1907	413,954 tons
1889	2,203 tons		

PRODUCTION OF SUGAR BEETS AND OF BEET SUGAR IN THE UNITED STATES, 1901-1907.

The following statements are taken from Report No. 86, Progress of the Beet-Sugar Industry in the United States in 1907:

The acreage planted to sugar beets in the United States in 1907, together with the percentage abandoned owing to unfavorable weather conditions, mistakes of growers, or other causes, is shown in the following table:

Acreage planted to beets in 1907.

State.	Planted.	Abandoned.	State.	Planted.	Abandoned.
	Acres.	*Per ct.*		*Acres.*	*Per ct.*
California	52,823	10.3	Wisconsin	13,800	14.2
Colorado	134,848	5.3	Ten other States	45,197	9.0
Idaho	29,051	10.7			
Michigan	95,302	7.3	The United States	400,953	7.5
Utah	29,932	4.2			

[a] In long tons of 2,240 pounds.

Comparison with the acreage harvested shows that about 30,000 acres, or 7½ per cent, of the acreage planted was abandoned. Comparison with the figures for the preceding year shows that the acreage planted exceeds that for 1906 by 3,338 acres, while the acreage harvested is about 5,000 less, the acreage abandoned in 1906 being only 5.2 per cent. The increased loss of acreage was due mainly to unfavorable spring weather, particularly in Wisconsin, Nebraska, Idaho, and California.

General factory and farm results.

BY STATES, FOR 1907.

State.	Factories in operation.	Area harvested.	Average yield of beets, per acre.	Beets worked.	Sugar manufactured.		Estimated average extraction of sugar.	Average sugar in beets.	Average purity coefficient of beets.	Average length of campaign.
					Pounds.	Tons.[a]				
		Acres.	*Tons.*[a]	*Tons.*[a]			*P. ct.*	*P. ct.*		*Days.*
California	8	47,387	10.23	484,816	146,045,500	73,023	15.06	17.9	85.1	73
Colorado	16	127,678	11.93	1,523,303	338,573,000	169,286	11.11	15.3	81.5	127
Idaho	4	25,938	9.41	244,080	75,928,200	37,964	15.55	17.8	88.3	88
Michigan	16	88,334	7.89	696,785	169,452,000	84,726	12.16	15.1	84.7	70
Utah	5	28,663	12.32	353,159	88,973,500	44,487	12.60	16.3	86.0	116
Wisconsin	4	11,837	10.37	122,800	30,320,000	15,160	12.35	15.1	85.6	61
States having but a single factory:[b] Illinois, Iowa, Kansas, Minnesota, Montana, Nebraska, New York, Ohio, Oregon, Washington	10	41,147	8.33	342,928	77,964,230	38,982	11.37	15.1	82.3	70
Totals and averages.[c]	63	370,984	10.16	3,767,871	927,256,430	463,628	12.30	15.8	83.6	89

TOTALS AND AVERAGES, BY YEARS, 1901-1906.[d]

		Acres.	*Tons.*[a]	*Tons.*[a]	*Pounds.*	*Tons.*[a]	*P. ct.*	*P. ct.*		*Days.*
1906	63	376,074	11.26	4,236,112	967,224,000	483,612	11.42	14.9	82.2	105
1905	52	307,364	8.67	2,665,913	625,841,228	312,921	11.74	15.3	83.0	77
1904	48	197,784	10.47	2,071,539	484,226,430	242,113	11.69	15.3	83.1	78
1903	49	242,576	8.56	2,076,494	481,209,087	240,604	11.59	[e]15.1	(*f*)	75
1902	46	[e]216,400	8.76	1,895,812	436,811,685	218,406	11.52	[e]14.6	[e]83.3	94
1901	36	175,083	9.63	1,685,689	369,211,733	184,606	10.95	14.8	82.2	88
Averages 1901-1906	.....	252,547	9.66	2,438,593	560,754,027	280,377	11.50	15.0	82.8	86

[a] Tons of 2,000 pounds each.
[b] Grouped together to avoid giving publicity to the data of individual factories.
[c] The average yield of beets per acre is found by dividing the total beets worked by the total acreage harvested; the average extraction by dividing total sugar produced by total beets worked; the average contents of sugar, coefficients of purity, and length of campaigns by adding the figures reported by the different factories and dividing by the number of factories reporting.
[d] Compiled from the annual reports on Progress of the Beet-Sugar Industry in the United States.
[e] These averages are not based on data for all the factories, as some of them failed to report results of tests, but it is believed that they fairly represent the average character of the total beet crops.
[f] No data reported.
[g] Based on reports from 27 factories and careful estimates for 15 others.

CONSUMPTION OF SUGAR IN THE UNITED STATES.

The following table shows the quantities of imported sugar (both cane and beet) consumed in this country during the past three years, the quantity of domestic cane, beet, and maple sugars, and the quantities of sugar made in this country from imported molasses. Of the total quantity consumed in 1907, nearly 80 per cent was imported either from foreign countries or the insular possessions of the United States, while less than 13 per cent was domestic beet sugar. The total annual consumption has nearly reached 3 million tons of 2,240 pounds.

Consumption of sugar in the United States, 1905–1907.

[According to Willett & Gray, January 9, 1908.]

Kind and origin.	1907.	1906.	1905.
	Tons.[a]	*Tons.*[a]	*Tons.*[a]
Cane and beet sugar from foreign countries and insular possessions	2,337,352	2,281,599	2,056,092
Cane sugar, Louisiana and Texas	264,968	267,947	334,522
Beet sugar, United States	375,410	300,317	220,722
Maple sugar	10,000	6,000	9,000
Molasses sugar, made in United States from foreign molasses	6,249	8,150	11,880
Total domestic sugar	656,627	582,414	576,124
Total consumption of all sugars	2,993,979	2,864,013	2,632,216

[a] Tons of 2,240 pounds.

The total annual consumption of sugar in the United States, the percentage of increase or decrease year after year, and the per capita consumption for the years 1884–1907 are shown in the table which follows. The total consumption has increased nearly 140 per cent, while the per capita consumption has increased over 52 per cent since 1884.

Consumption of sugar in the United States for twenty-four years, 1884–1907.

[According to Willett & Gray.]

Year.	Total amount sugar consumed.	Increase (+) or decrease (−).[a]	Consumption per capita.	Year.	Total amount sugar consumed.	Increase (+) or decrease (−).[a]	Consumption per capita.
	Tons.[b]	*Per cent.*	*Pounds.*		*Tons.*[b]	*Per cent.*	*Pounds.*
1884	1,252,366	+ 7.01	51.00	1896	1,940,086	−0.49	60.90
1885	1,254,116	+ 0.14	49.95	1897	2,070,978	+6.75	63.50
1886	1,355,809	+ 8.11	52.55	1898	2,002,902	−3.29	60.30
1887	1,392,909	+ 2.74	53.11	1899	2,078,068	+3.75	61.00
1888	1,457,264	+ 4.62	54.23	1900	2,219,847	+6.83	66.60
1889	1,439,701	− 1.21	52.64	1901	2,372,316	+6.87	69.70
1890	1,522,731	+ 5.77	54.56	1902	2,566,108	+8.17	72.80
1891	1,872,400	+22.96	67.46	1903	2,549,642	−0.64	70.90
1892	1,853,370	− 1.02	63.76	1904	2,767,102	+8.53	75.30
1893	1,905,862	+ 2.83	63.83	1905	2,632,216	−4.88	70.50
1894	2,012,714	+ 5.55	66.64	1906	2,864,013	+8.81	76.10
1895	1,940,744	− 3.13	64.23	1907	2,993,979	+4.54	77.54

[a] As compared with the preceding year. [b] Tons of 2,240 pounds.

Although in recent years the beet-sugar industry has made great strides in the United States, and there has been some growth of the cane-sugar industry, the increase in production has not by any means kept pace with the increase in consumption. In fact, much more foreign sugar is consumed now than was the case ten years ago. In 1897 our total consumption of sugar was 2,070,978 long tons; in 1907 it was 2,993,979 tons, an increase in ten years of 923,000 tons. During the same period the increase in domestic production has been only about 350,000 tons.

SUGAR IMPORTED FOR CONSUMPTION.

The next table shows the character of the sugar imported for consumption, and its origin. Nearly 85 per cent of the sugar imported comes from Hawaii, Porto Rico, the Philippines, and Cuba under tariff concessions, while only about 15 per cent comes from other countries and pays full duty. The imports from both Porto Rico and Cuba are steadily increasing, Cuba alone furnishing about 58 per cent of the foreign sugar consumed in the United States in 1907, and about 45 per cent of the total sugar consumed. It will be noticed that nearly all the imported sugar consumed in the United States is made from cane; in 1906 less than 8 per cent was from beets, and in 1907 less than 1 per cent. In fact, if the sugar made in the United States be included, it appears that only about 13 per cent of the sugar consumed in this country in 1907 was made from beets.

Consumption of imported sugar, 1905–1907.

According to Willett & Gray.

Kind and origin.	1907.	1906.	1905.
Imports on which tariff concession is allowed:[a]	*Tons.*[b]	*Tons.*[b]	*Tons.*[b]
From Hawaii, cane sugar	418,102	343,857	376,497
From Porto Rico, cane sugar	212,853	193,978	124,928
From Philippines, cane sugar	10,700	41,900	14,673
From Cuba, cane sugar	1,340,400	1,165,994	1,101,611
Total	1,982,055	1,745,729	1,617,709
Imports on which full duty is assessed:[c]			
Foreign sugar—			
Raw cane	347,509	357,057	412,560
Raw beet	6,780	175,827	22,161
Refined beet	949	2,734	1,844
Refined cane	59	252	1,818
Total	355,297	535,870	438,383

[a] Sugar from Hawaii and Porto Rico is admitted free of duty; that from the Philippines at 25 per cent below the regular rate, and that from Cuba, under the reciprocity treaty, at 20 per cent less than the regular rate.

[b] Tons of 2,240 pounds.

[c] The regular rates of duty on raw sugar vary from 95 cents to $1.75½ per hundred pounds, depending on the character of the product; the regular rate on refined sugar is $1.95 per hundred pounds.

THE WORLD'S SUGAR CROP.

The following table was prepared in the Bureau of Statistics, U. S. Department of Agriculture, and published in Progress of the Beet-Sugar Industry in the United States in 1907.

Sugar production of the world, 1903–1907.[a]

Country.	1903–4.	1904–5.	1905–6.	1906–7.	1907–8.
CANE SUGAR.					
United States:	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Louisiana and Texas	248,277	350,000	342,000	243,000	347,000
Hawaii	328,103	380,576	383,225	392,871	420,000
Porto Rico	130,000	145,000	213,000	210,000	217,000
Total United States[b]	706,380	875,576	938,225	845,871	984,000
Cuba	1,040,228	1,163,258	1,178,749	1,427,673	1,200,000
Other West Indies	268,306	244,837	302,163	279,631	291,000
Mexico	107,547	107,038	107,529	108,000	115,000
Central America	21,450	19,768	18,516	19,000	19,000
South America	601,134	590,382	700,001	610,151	586,000
Total America	2,745,045	3,000,859	3,245,183	3,290,326	3,195,000
Asia	2,876,671	3,333,672	2,926,209	3,455,446	3,481,477
Africa	355,747	251,340	317,967	349,000	270,000
Oceania	163,328	216,213	230,000	249,000	276,000
Europe	28,000	18,592	15,722	16,400	11,000
Total cane-sugar production	6,168,791	6,820,676	6,735,081	7,360,172	7,233,477
BEET SUGAR.					
United States	214,825	216,173	279,393	431,796	413,954
Canada	6,710	8,034	11,419	11,367	7,943
Total America	221,535	224,207	290,812	443,163	421,897
Europe:					
Germany	1,927,681	1,598,164	2,415,136	2,238,000	2,135,000
Austria-Hungary	1,167,959	889,373	1,509,870	1,344,000	1,460,000
France	804,308	622,422	1,089,684	756,000	725,000
Russia	1,206,907	953,626	968,000	1,470,000	1,410,000
Belgium	209,811	176,466	328,770	283,000	235,000
Netherlands	123,551	136,551	207,189	181,000	175,000
Other countries	441,116	332,098	415,000	445,000	435,000
Total Europe	5,881,333	4,708,700	6,933,649	6,717,000	6,575,000
Total beet-sugar production	6,102,868	4,932,907	7,224,461	7,160,163	6,996,897
Total cane and beet sugar production	12,271,659	11,753,583	13,959,542	14,520,335	14,230,374

[a] In long tons, of 2,240 pounds, except in the case of European beet-sugar production, which has been retained in metric tons of 2,204.622 pounds, as originally estimated by Licht; United States beet-sugar data were obtained from reports of Department of Agriculture on the Progress of the Beet-Sugar Industry in the United States; other data from official statistics of various countries, and from Willett & Gray.

[b] Not including the Philippine Islands, which are included under Asia.

THE BEET-SUGAR INDUSTRY OF EUROPE.

The foregoing table shows the enormous proportions to which the beet-sugar industry has developed throughout central Europe and especially in Germany, Austria, and Russia. The following table contains additional data showing the magnitude of the industry:

Number of factories, yield of beets per acre, and yield of sugar in the principal beet-sugar countries of Europe.[a]

Items.	Germany.	Austria-Hungary.	France.	Russia.	Belgium.	Holland.	Sweden.	Denmark.
Acres grown in beets	1,097,132	844,987	494,158	1,443,591	148,941	108,872	72,927	38,038
Average tons per acre[b]	12.91	10.59	11.04	7.16	12.39	11.01	13.82	12.49
Number of factories	369	206	277	280	83	28	19	7
Average tons worked at factory	38,390	43,433	19,695	36,918	22,240	42,809	53,019	67,879
Percentage of extraction of sugar	15.52	14.91	13.42	14.03	15.25	14.71	15.64	13.98

[a] F. Sachs in La Sucrerie Belge, August, 1907. [b] Tons of 2,204 pounds.

CONSUMPTION OF SUGAR IN EUROPE.

Mr. F. O. Licht, a high authority on European beet-sugar statistics, in a report dated February 21, 1908, estimates the per capita consumption of sugar in European countries as follows:

European per capita consumption of sugar for the year 1906–7.

	Pounds.		Pounds.
Germany	40.92	Portugal and Madeira	15.51
Austria	24.32	England	93.50
France	36.05	Bulgaria	7.98
Russia	20.55	Greece	10.16
Holland	41.40	Servia	6.92
Belgium	29.70	Turkey	11.73
Denmark	73.68	Switzerland	55.22
Sweden and Norway	47.88		
Italy	7.63	All Europe	31.61
Roumania	7.83	United States	77.54
Spain	11.37		

The foregoing table shows that the United States consumes more sugar per capita than any other nation except England, the consumption in this country being about two and a half times as much as for Europeans in general.

O

Return to Forage Crop Investigation files.

Issued September 29, 1910.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN 52.

THE SUGAR BEET

CULTURE, SEED DEVELOPMENT, MANUFACTURE, AND STATISTICS.

BY

H. W. WILEY,

Chief of the Bureau of Chemistry, and formerly Director of the Department Sugar Beet Experiment Station in Nebraska.

[Fourth Revised Edition, July, 1910.]

By A. HUGH BRYAN,

Chief, Sugar Laboratory, Bureau of Chemistry.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY,
Washington, D. C., June 30, 1910.

SIR: I have the honor to transmit for your approval the fourth revision of Farmers' Bulletin No. 52, on the sugar beet, prepared by Mr. A. H. Bryan, chief of the sugar laboratory, who has had practical experience in the beet-sugar industry. This bulletin was last revised in 1908, having been originally issued in 1897 and first revised in 1899. Extensive changes were made in 1908 in order that the most recent practices in sugar-beet culture might be given; references to the work of the Bureaus of Entomology and Plant Industry bearing on diseases of the sugar beet, pests attacking it, and the development of the single-germ seed were also inserted. In this revision no changes have been made in the text other than to bring the statistics up to date.

Respectfully,

H. W. WILEY, *Chief.*

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE SUGAR BEET.

INTRODUCTION.

The successful growing of sugar beets is an art that one acquires by practice. The farmer who has made a success of raising other crops will quite often fail at first in this one, as the methods of cultivating ordinary crops do not apply in the case of sugar beets. Certain directions for the preparation of the soil, the planting, thinning, and harvesting must be followed in beet culture. Although it is possible to raise sugar beets with little regard to these directions, such a crop will usually fail to pay for itself either because the yield is too small or the sugar content of the beets too low to meet factory requirements. In commercial beet growing, therefore, carelessness leads quickly to failure, while careful regard for details spells success. Success comes at first from following the advice of successful growers, and later it may be augmented by practical experience. Certain economies can be practiced, but they should never consist in planting a smaller quantity of seed than is prescribed, nor in locating the beet field on poor land.

In the manufacture of sugar from the beet, the farmer plays an important part by supplying beets in an adequate quantity and of a high quality; but beyond that he can hardly hope to enter the field. The manufacture of beet sugar is an industry entirely distinct from agriculture, and can only be successfully accomplished by the investment of large capital and the employment of skilled artisans. From the nature of the process it is quite improbable that any simple method of home manufacture of beet sugar will ever prove commercially successful. The juice of the beet is extracted with difficulty. It contains considerable quantities of mineral salts and organic substances, which render the crude sugar and molasses therefrom unpalatable. Simple processes for the extraction of the juice can at best remove only 60 to 70 per cent of the sugar which the beet contains, and thus a percentage of loss is incurred which at the very outset renders it impossible for a home apparatus to compete with a large factory. Beet sugar, for the reasons given above, can not be used in the raw state, as is the case with the products derived from the sugar cane, sorghum, and the maple tree. The refining of the sugar requires a heavy outlay for machinery and a high degree of supervisory skill. It can not, therefore, be accomplished upon the farm.

The beet-sugar industry offers a great opportunity for the profitable extension and diversification of agricultural industries in this country. The sugar beet is proving a profitable crop for the farmers not only in old settled areas where it must compete with a large list of established crops, but in the newly developed regions of the West where its adaption to intensive farming makes it a favorite crop for culture under irrigation. Its influence in developing stock breeding, feeding, and dairy industries is attracting the favorable attention of farmers interested in these pursuits. The rapid extension of the industry during the past few years shows that its value is gaining recognition; and there appears to be no valid reason why this extension should not continue until all the sugar consumed in the United States is made from crops grown by American farmers.

TEMPERATURE CONDITIONS AFFECTING THE BEET-SUGAR INDUSTRY.

Experience has shown that the sugar beet reaches its highest development in north temperate latitudes. So far as the production of beets with high tonnage is concerned, it is found that this can be accomplished far to the south, but beets grown there are, on the whole, less rich in sugar and less suitable for the manufacture of sugar than those grown farther north. It must be remembered, however, that the expressions north and south do not refer to any absolute parallels of latitude, but rather to isothermal lines, which in many cases vary widely from the parallels of latitude and in some cases cross them almost at right angles.

Theoretical beet-sugar belt.—As a result of many years of careful experimentation, it may be said that as far as temperature alone is concerned the sugar beet attains its greatest perfection in a zone of varying width through the center of which passes the isothermal line of 70° F. for the months of June, July, and August. This zone for this country is shown in the accompanying map (fig. 1).

This isothermal line, for the United States, begins near the city of New York and passes up the Hudson River to Albany; thence turning westward, it runs near Syracuse and passes in a southwesterly direction, touching the shore of Lake Erie near Sandusky, Ohio; turning thence in a northwesterly direction, it enters Michigan and reaches its highest point in that State near Lansing; then going in a southwesterly direction, it enters the State of Indiana near South Bend, passes through Michigan City, then in a northwesterly course continues through the cities of Chicago and Madison, reaching its highest point near St. Paul, Minn.; thence it extends in a southwesterly direction until it enters the State of South Dakota, where it turns again northwest and reaches its highest point in Dakota just above the forty-fifth parallel of latitude, where it crosses the Missouri River. The iso-

thermal line then turns almost due south, following very closely the one hundred and first degree of longitude until it leaves the State of

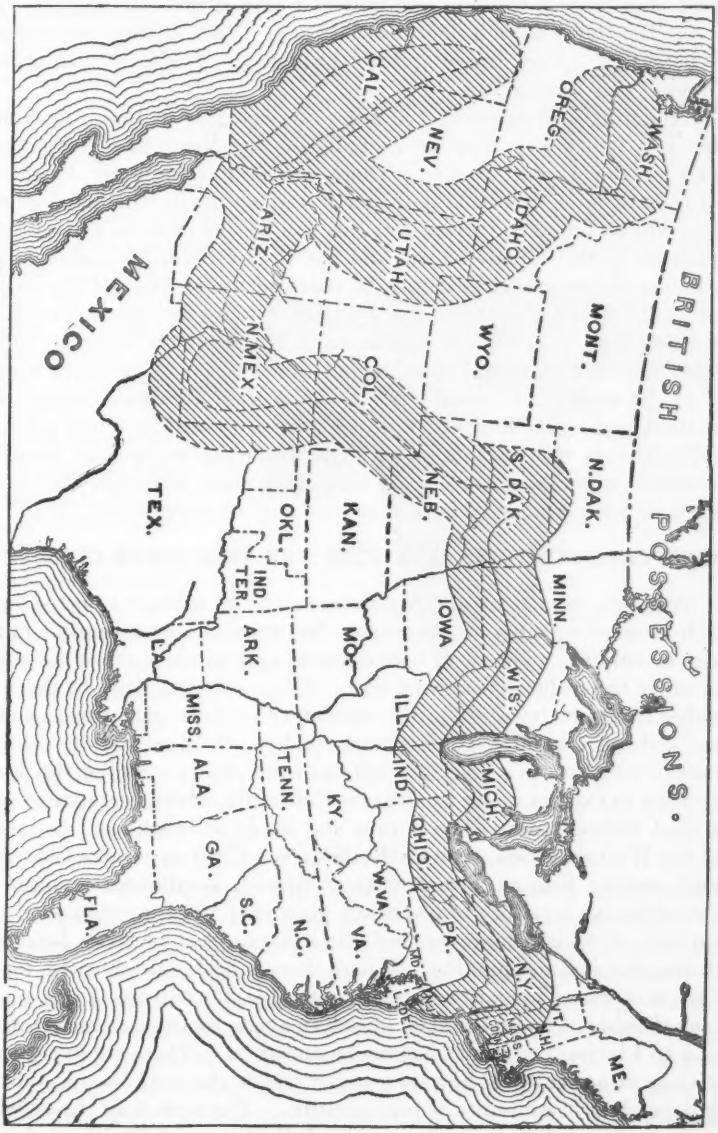

Fig. 1.—Temperature zone in which the sugar beet attains its greatest perfection.

Nebraska near the northeast corner of Colorado; passing in a southwesterly direction through Colorado, it reaches, at Pueblo, almost to

the one hundred and fifth degree of west longitude, whence it passes in a slightly southeasterly direction into New Mexico, turns to the west, and crosses the one hundred and fifth degree of longitude at about the thirty-second degree of latitude. Then turning westward, it passes in a very irregular line through the States of California, Oregon, and Washington.

Extending a distance of 100 miles on each side of this isothermal line is a belt which may be regarded as the theoretical beet-sugar area of the United States. There are doubtless many localities lying outside of this belt, both north and south, in which the sugar beet will be found to thrive; but this will be due to some exceptional qualities of the climate or soil and not to any favorable influence of a higher or lower temperature. A study of the location of the sugar factories operating to-day will show that only five factories are outside of these lines. A mean temperature of 70° F. in the summer, however, must not be regarded as the only element of temperature which is to be taken into consideration. In those localities where the winters come early and are of unusual severity will be found greater difficulties in the production of sugar from the sugar beet than in localities where the winters are light and mild, although the mean summer temperature of both localities may be represented by 70° F.

MOISTURE CONDITIONS AFFECTING THE BEET-SUGAR INDUSTRY.

Although conditions of temperature must be taken into consideration in selecting sites for beet-sugar factories, those of rainfall must also be studied. The sugar beet requires a certain amount of moisture in order to produce its normal crop. This moisture must be derived either from precipitation in the usual way or from irrigation; or else the soil must be of that particular quality which will allow subterranean moisture to reach the rootlets of the plants. Soil of this kind appears to exist in many localities in California, where beets are grown almost without rain. The porous and sandy soils adjacent to many of the Western rivers, such as the Arkansas River in eastern Colorado and western Kansas, also appear to furnish a sufficient amount of subterranean moisture to produce a good crop in connection with the rainfall, of which, however, but little is expected in those localities during the summer months. Where there is little subterranean moisture, and where irrigation is not practicable, the culture of the sugar beet should not be undertaken unless an average summer precipitation of 2 to 4 inches per month can be depended on. There are many conditions of agriculture, however, under which the beet becomes quite independent of extremes of precipitation. The beet may thrive with very little rainfall or with a great deal, if properly cultivated in a suitable soil.

GROWING BEETS ON IRRIGATED LANDS.

The experience of more than twenty years in California and ten years in Colorado has shown that the climatic data, regarded as of prime importance in beet culture in Europe, can not be regarded as rigidly applicable to this country. The successful growth of sugar beets in the arid regions of our country, with irrigation, has introduced a new factor into the science of beet meteorology. While the arid area on which beets can be grown without irrigation is probably confined almost exclusively to the coast valleys of California, the successful commercial production of sugar beets in Utah and Colorado has opened a new and extensive field. What has taken place in these States is being rapidly duplicated in Idaho; a beginning has been made in Montana, and the time is undoubtedly coming when beets will be grown in Wyoming and probably throughout the whole arid region.

FIG. 2.—Kleinwanzlebener sugar beet.

The northern parts of our Eastern and Middle States and the States of Oregon and Washington have at least an equal chance for the successful production of beet sugar with the fields of Germany and France. The irrigable parts of the great Southwest have advantages of soil and climate which will enable them to enter into competition in the production of beet sugar. To be able to control the moisture of the soil is a matter of prime importance to the beet grower. In the arid region the time at which the beet matures can be controlled by withholding the water. Furthermore, there is no danger of loss due to second growth, so easily induced by late warm autumnal rains.

The high cost of good irrigation renders it imperative that the areas under culture be devoted to a crop which is capable of producing a

more valuable yield than is afforded by cereal culture. In a dry soil the beet can endure without damage a low temperature, which would prove quite disastrous in a wet climate. More complete maturity may be thus obtained, and a more leisurely harvest. In fact, there is no staple crop which can compete with the sugar beet in demanding the favorable attention of those interested in irrigation. If a net profit of from $10 to $20 per acre can be secured, from $100 to $200 per acre can be paid for the land. It is estimated that nearly 80,000,000 acres of land in the arid regions of the United States may eventually be irrigated, being nearly one-fifth of the total area. Of this area perhaps 10 per cent is capable of easy and speedy irrigation. One million acres planted to beets would yield, under intensive culture, a quantity of sugar sufficient, with the Louisiana product, for domestic consumption. There is nowhere in sight a more promising prospect for agricultural development than in the production of sugar beets on irrigated lands.

VARIETIES OF BEETS.

Botanically all kinds of sugar beets are of the same species as the common garden beet (*Beta vulgaris*). The differences between varieties have arisen from selection and breeding. Certain valuable peculiarities resulting from natural variations or mutations have, through careful selection, been *fixed*, and pure strains having these superior qualities associated with certain distinguishing external characters have been developed.

The shape and size of the beet, its color, the character of the foliage, whether erect or spreading, etc., are the most frequent marks of distinction. The beets are also frequently designated by the names of those who have developed them, or by the name of the town or locality in which they have been grown.

Among the more frequently occurring varieties grown in Europe may be mentioned the Improved Kleinwanzlebener, the Kleinwanzlebener, and the Vilmorin, the two latter being most widely known in this country. Sugar manufacturers prefer those varieties which yield a high percentage of sugar, since the juices are purer and the expenses of manufacture and the cost of the raw material are less. Large beets yielding a large tonnage were usually grown in Europe prior to the adoption of legislation placing a tax on the beet itself instead of on the sugar, and were preferred on account of the value of the pulp for cattle feeding.

The certainty that the seed has been grown according to the most scientific methods is of great importance to the beet grower and sugar manufacturer, since the former may depend upon producing rich beets and receiving fair compensation for his labor and the latter is enabled to operate his factory economically. The beet has reached

such a high state of perfection as to make the least degree of laxity in its treatment exceedingly dangerous to its qualities.

The best beet for general cultivation is probably the Kleinwanzlebener, which seems now to have a wider cultivation in this country than any other variety. The general character of this beet is shown by figure 2. It has a conical root, straight and even, quite large at the head and rapidly tapering, and is distinguished from the Improved Vilmorin by its brighter color and its lighter-colored leaves, which are beautifully undulating or scalloped about the edges. Coming from a cross in which the Improved Vilmorin entered largely, the Kleinwanzlebener is to-day a fixed variety and is equally well produced in France and Germany. It succeeds in soil of an alluvial nature and average richness and on level plateaus. In soils very rich in humus it ripens poorly and loses much of its richness. Like the Improved Vilmorin, toward the end of the growing season its leaves are completely spread. Under those conditions of culture where the Improved Vilmorin gives from 12 to 16 tons per acre, the Kleinwanzlebener gives from 14 to 18 tons; and from these beets 13 to 18 per cent of sugar can be obtained.

FIG. 3.—White Improved Vilmorin sugar beet.

The other general type, the Vilmorin, is illustrated in figure 3. This beet is the result of thirty-five years of methodic and persevering selection based upon the lines to be indicated hereafter. In regard to its preservation, it is recognized that it holds its sugar content as well as any other variety. In those factories in Germany and France in which sugar is manufactured from the Improved Vilmorin in connection with other varieties it is the custom to reserve this variety for the end of the season and to work up the less reliable beets at an earlier date. It is also said to resist better than any other

variety the unfavorable influence of certain characters of soil and of certain manures. In black soils, rich in organic matter, it gives great results, while most other varieties of beets become watery or saline in excess. Excessive quantities of nitrogenous fertilizers, which are carefully excluded from ordinary varieties, can be applied with safety to the Improved Vilmorin; a great number of experiments have shown that this can be done without serious deterioration in the quality of the beet and with a considerable increase in weight. However, experiments with Kleinwanzlebener beets show that they are also susceptible to the influence of such fertilizers, as is shown by a gain in tonnage when fertilized. From thousands of analyses it has been established that about 16 per cent of sugar can be obtained with the Vilmorin and that under favorable conditions from 12 to 16 tons per acre can be raised.

In this country considerable quantities of beet seed have been grown at Fairfield, Wash., and also by the Utah-Idaho Sugar Company in Utah and Idaho chiefly, in the latter case, for its own use. In California and Michigan also some seed is produced.

Within the last six years the Department of Agriculture has been doing considerable work in endeavoring to develop a strain of beets bearing single-germ seed balls (see p. 30) and in growing seed better adapted to the requirements of this country. Considerable progress has been made along these lines. The farmer growing beets for a factory does not have to consider these points to any great extent, as the factories buy the seed and then furnish it to their growers. It is of prime importance that the factory purchase the best seed, and they are better able to judge as to the kind of seed desired and to test its vitality.

CULTURE OF SUGAR BEETS.

Farmers who raise beets for a sugar factory are not left entirely to their own resources in growing the crop. They enter into a contract with the factory management which outlines the methods to be employed. Then the factory employs an agricultural superintendent and a corps of assistants whose duty it is to go among the growers giving instructions and suggestions regarding the selection and preparation of the soil, planting, cultivation, time of harvesting, etc. These men are of course well informed on all phases of beet culture, and they are usually able to make valuable suggestions in regard to the cultivation of other crops grown in rotation with beets. Their instructions and influence, therefore, tend to improve the farm practice of communities in which sugar beets are grown.

SELECTION OF SOIL.

The sugar beet does not require a particular kind of soil for its proper production. In general, soils are described for practical purposes as clayey, sandy, loamy, or alluvial soils; all of these soils will produce beets. The black prairie soils also have been found, with proper cultivation, to produce excellent beets. Perhaps the best soil may be described as a sandy loam, a soil in which there is a happy equilibrium of organic matter, clay, and sand.

New land should not be selected to grow sugar beets, for the crop is not a good reclaimer of soils; and especially to be avoided is new land containing decaying vegetable matter, which produces only rank growth with low sugar content. Preferably the most productive land on the farm should be used, such a soil as will yield a good crop of Indian corn, wheat, or potatoes. The soil should neither be so compact as to interfere with cultivation to a depth of 10 or 12 inches nor have a tendency to bake hard. It may contain some alkali, as sugar beets are not especially susceptible to injury from this constituent. The soil should be reasonably level, but it should also be well drained. Natural drainage on level soil being somewhat deficient, tile drainage may be practiced with advantage.

FERTILIZATION.

Happily, in most American soils there is still sufficient natural fertility to produce a good crop of sugar beets; whereas in the soils of Europe, where sugar beets have been grown for years, the farmers must depend on fertilizers to insure a remunerative crop.

The principles of fertilization depend upon the fact that a soil should have returned to it all that the harvest has removed, and an unproductive soil be supplied with those elements in which it is deficient.

The soil ingredients most essential for the successful production of sugar beets are nitrogen, phosphoric acid, potash, and lime.

The following are the quantities of these constituents in 1,000 pounds of beet roots and in an equal quantity of beet leaves, as determined by numerous analyses:

Constituents.	In 1,000 pounds of roots.	In 1,000 pounds of leaves.
	Pounds.	*Pounds.*
Potash	3.3	6.5
Phosphoric acid	0.8	1.3
Nitrogen	1.6	3.9
Total ash	7.1	18.1

It will be seen from the foregoing table that, for equal weights, the leaves make a heavier drain on the plant-food elements of the

soil than do the roots. The disposition to be made of the leaves is therefore a matter of considerable importance. By leaving them on the land the plant-food elements which they contain will be returned to the soil. If they are removed for feeding, the need for applications of commercial fertilizers is increased. The leaves may, however, be fed and the resulting manure may be returned to the soil without material loss of these fertilizing constituents; or in some cases stock may be turned into the beet fields to feed on the tops and leaves remaining on the ground after the harvest is completed.

Most soils contain a sufficient quantity of lime, although there are some in which the supply of lime is naturally deficient; and such soils would be benefited by an application of land plaster, burned lime, phosphatic slags, or ground shells. Phosphoric acid and potash are supplied in the form of ordinary commercial fertilizers—the phosphorus as ground bone, superphosphate, or basic slag, and the potash may be supplied in the form of muriate or sulphate of potash or as kainit.

Nitrogen may be supplied in the form in which it exists in ground bone, or from the refuse of the slaughterhouses in the form of dried blood and tankage, or as cotton-seed meal or oil cake, or as nitrate of soda, sulphate of ammonia, etc.

Barnyard manure offers a ready means for fertilizing the soil, and one which every farmer can employ. By its use, humus is added to the soil as well as small percentages of potash, phosphoric acid, and nitrogen. There is a great difference of opinion as to the best time and method for applying it to beet land. In general, however, it should be applied, in a well-rotted condition, in the autumn before the ground is plowed. The quantity per acre depends, of course, on the fertility of the soil; but in any case it is not best to apply a very heavy dressing. With poor soils it is best to apply the manure for several years in succession, rather than to apply enough at once to bring it up to the required state of fertility. Too copious an application of manure is apt to produce overgrowth in the beets, which makes them ill suited to the manufacture of sugar. If the manure be applied in an unrotted condition it is apt to seriously injure the crop in case of dry weather.

As to the relation which the quantity of material returned to the soil should bear to the quantity abstracted by the beet, it may be said in general that it is desirable to return as much nitrogen, from one and a quarter to one and a half times as much potash, and two and a half times as much phosphoric acid as have been removed by the roots. Greater additions of potash and phosphoric acid have no disadvantageous effects upon the crop. But it must not be expected, on the other hand, that increasing fertilization, especially

with potash, will produce proportionately increasing crops, as has been asserted by some.

As regards the use of nitrate of soda for fertilization, if applied late to the beet crop, it prevents its ripening, thereby lowering the sugar content. It is best applied early and in small quantities. Heavy applications are thought to injure the beet for manufacturing purposes.

CROP ROTATION.

Every farmer should understand that he can not continuously grow any crop on the same ground and secure maximum results. Many try to do this, but they do it to their own loss and the depletion of the soil.

One of the great objects of crop rotation is to bring about and maintain an equilibrium of soil constituents and conditions. The best rotation is the one in which the method of culture and action of the plant each year leave the soil in the best condition for the following crop. Beets do best after alfalfa, corn, or small grains.

A good scheme of rotation is, first, wheat; then beets; then clover for two years, the last crop being plowed under; then potatoes, wheat, and beets in the order mentioned. If alfalfa can be grown, it should be included in the rotation of crops. Also in some sections potatoes do well in the rotation. By this method, and a judicious use of stable manure and commercial fertilizers, the fertility of the soil can be maintained and even increased. Beets do well after small grain crops, because these, being harvested early, leave the ground ready for late autumn plowing, an important point in successful beet culture.

PREPARATION OF THE LAND FOR PLANTING.

The field in which beets are to be planted should be selected and plowed in the late autumn to the depth of at least 9 inches. As a rule the plow in each furrow should be followed by a subsoiler, which will loosen the soil to the depth of 6 or 7 inches more. A convenient subsoil plow is shown in figure 4. Each field to be planted in beets should thus have the soil prepared by thoroughly loosening it to the depth of from 15 to 18 inches. The land, being exposed through the winter, becomes quite mellowed, and in the spring can in many cases be prepared for planting by thoroughly cultivating the surface of the soil until it is reduced to perfect tilth. The large cultivator shown in figure 5 can be conveniently used for this purpose, followed when necessary by a harrow and roller. Too much can not be said of the importance of correct preparation of the ground before seeding, as on this condition the crop depends to a large extent. The seed bed should be uniformly well pulverized. It is desirable, however, that

each portion of the field to be planted should be thoroughly prepared immediately before the planting takes place. For instance, if the planting is to be made on a given day, the soil should be thoroughly

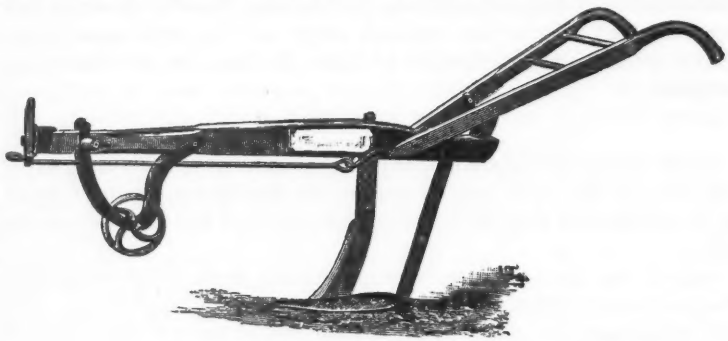

FIG. 4.—Subsoil plow.

prepared on the previous day. Thus all weeds and grasses which have started to grow are killed, and the beets have an even chance with the weeds for growth. If, on the other hand, the soil be prepared a week or even a few days before planting, the weeds and

FIG. 5.—Cultivator for sugar beets.

grasses get a good start, and it is difficult to free the beets therefrom. In case the ground has to stand any time before seeding after being prepared, it should be constantly and thoroughly cultivated.

PLANTING THE SEED.

Hand planting of the seed may be practiced when a very small plat is to be put in beets, but where a field embracing an acre or more is to be planted it is not convenient. In such cases planting by drill is best. Almost any garden drill can be adapted to use with beet seed. Special drills for sugar-beet seed are made by many manufacturers of agricultural implements. In planting by drill it is necessary to use from 15 to 20 pounds of seed per acre; in planting by hand from 10 to 15 pounds will be found sufficient.

A very convenient hand drill, which is especially fitted with a beet-seed dropping apparatus, is shown in figure 6. This machine marks the row, excavates the furrow, drops the seed at any required distance, and covers it.

FIG. 6.—Hand seed drill.

The beets should be covered to a depth of one-half inch to 2 inches, according to the state of the soil. If the soil be moist and in excellent condition, the beet seed should not be covered more than half an inch. If, on the other hand, the soil be very dry and early rains are not probable, the seed should be covered to a depth of 2 inches.

In the matter of space between rows there is considerable variation. In some cases the rows are made only 16 inches apart, and in others as wide as 28 inches. In recent years the tendency has been to increase rather than diminish the distance, though much depends on the soil and local conditions. It is argued by many that the greater ease and economy of culture with the wider rows outweigh the increased yields per acre which may be secured in the narrower rows.

When a considerable acreage is planted, it is important to be able to plant two or more rows at a time. The accompanying illustration (fig. 7) shows a seed drill which plants four rows at once.

In planting by hand or by drills an effort should be made to drop the seeds singly and at equal distances apart.

Under irrigation planting can be accomplished at almost any time, as the ground can be irrigated, then cultivated, and the seed planted at once.

Beets should be planted as early in the spring as practicable, but the ground should have sufficient moisture and warmth to cause germination of the seed. Experience has shown that the early-planted beets almost uniformly produce a larger yield with a higher content of sugar than the late-planted. No exact date can be fixed which would be suitable to all localities. In most of the localities in

FIG. 7.—Four-row seeder.

the beet area or the United States it will not be found practicable to plant earlier than the first week in May. In exceptional seasons a part of the sowing can be accomplished in April. On the Pacific coast, especially in central and southern California, the sowing can take place at a much earlier date. In parts of California planting is done in December with favorable results. But if planted too early, some of the beets will go to seed before harvest time. When this happens the percentage of sugar is diminished.

Most factories, by way of inducement to early planting, offer free seed for replanting any beet fields that may be injured by frost or other unfavorable conditions. This early planting makes it possible for the factory to begin its campaign earlier in the fall.

CULTIVATION.

To prevent the formation of a crust, and to keep the weeds and grass from getting a start, it is often necessary to cultivate the beet field with a spike harrow before the plants come up and to continue such cultivation until the beets are large enough for row cultivation to begin. Cultivation must not be postponed or neglected unless wet ground makes it impossible. The purpose of cultivation is two-

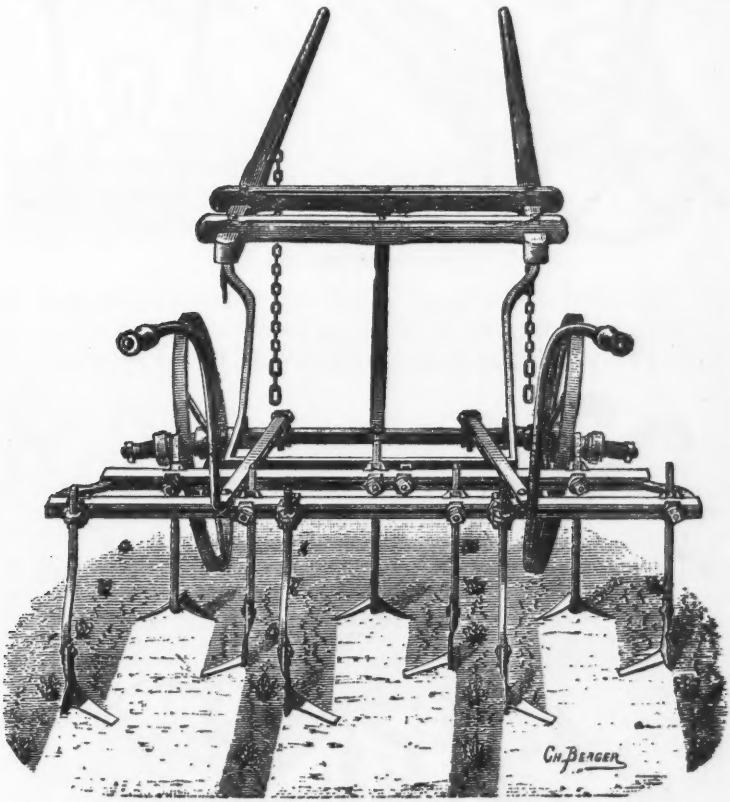

FIG. 8.—Horse hoe.

fold: (1) To hold the moisture in the soil; (2) to destroy the weeds and grass, as in the early stages of the beet's growth these can spoil the stand by choking the plants. When the land becomes dry is the most important time for cultivation in order to prevent the escape of moisture from the soil. Cultivation should be continued until the beets have attained such a size that the leaves cover the ground.

When large fields are cultivated, the horse hoe, a model of which is shown in figure 8, may be used. For smaller fields a similar apparatus propelled by hand may be employed. Convenient implements of

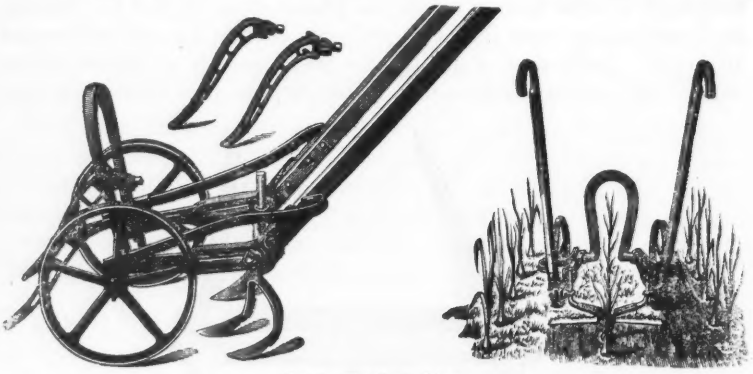

FIG. 9.—Hand-wheel hoes.

this kind are shown in figures 9 and 10. This implement frees the spaces between the rows of beets from weeds, and guards are used to prevent the growing beets from being covered by the loose soil.

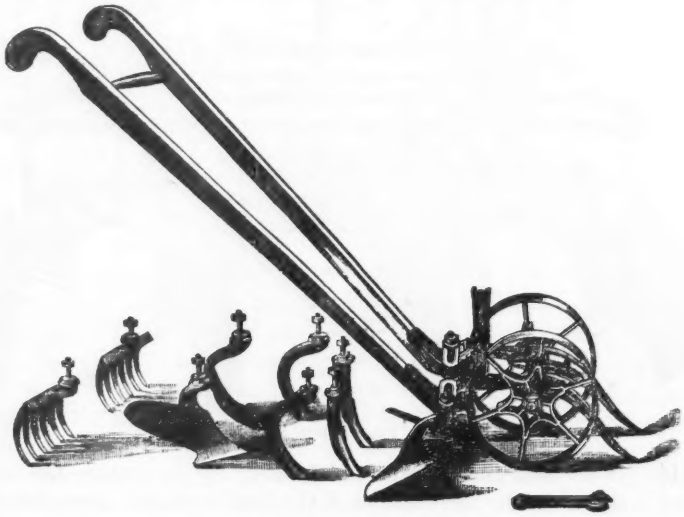

FIG. 10.—Cultivator for beets.

In growing beets with irrigation a cultivator which will prepare the furrow for conducting the water over the field is important. Such a device is shown in figure 11. In this implement the plow shown in the

rear of the cultivator teeth forms the required furrow and can be set at any required depth.

In the cultivation of large areas an implement adapted to four rows of beets is desirable. Such an implement, however, can not be

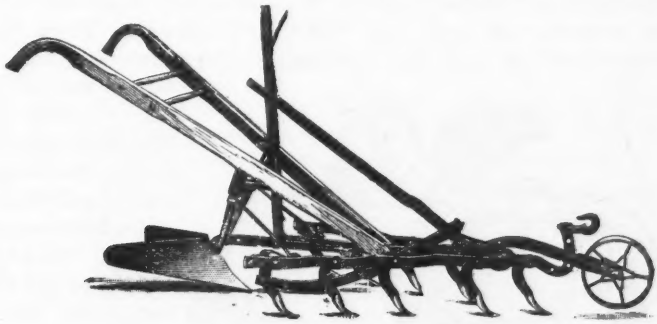

FIG. 11.—Beet cultivator for irrigated lands.

advantageously used, except in those cases where the beets have been sown with an implement planting four rows at a time. The cultivator shown in figure 12 is suitable for use on fields which have been planted

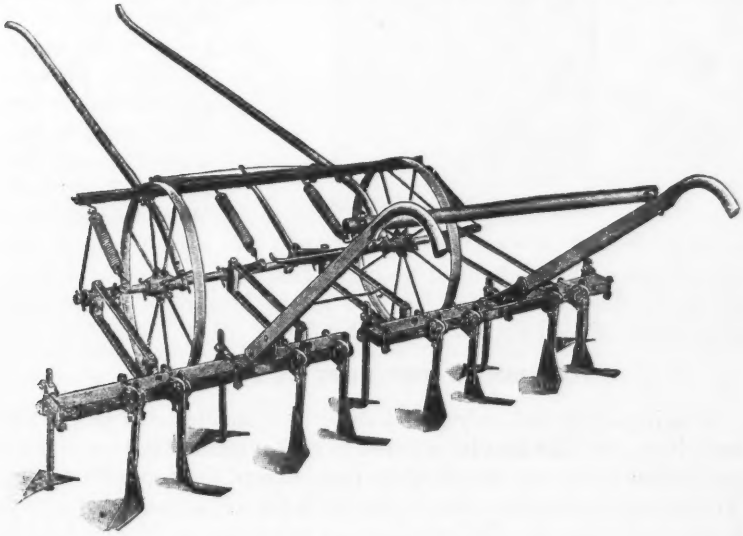

FIG. 12.—Four-row beet cultivator.

with the seeder shown in figure 7. Different kinds of devices for cultivation can be easily attached so that the implement can be used as a plow, a cultivator, or a harrow.

BUNCHING AND THINNING.

When the beets show three or four leaves, they should be bunched and thinned. The bunching is best accomplished with a short-handled hoe. One stroke of this implement takes out all the beets in the row except small bunches from 8 to 10 inches apart, depending on the width between the rows and other circumstances. From these bunches should be removed by hand all the plants but one, the largest and healthiest. Great care should be exercised in this work, and by careful selection all of the inferior plants will be removed. On the proper thinning, the tonnage largely depends. This does not mean that less space should be left between the plants. If the rows be 18 to 24 inches apart, the space between plants can vary from 8 to 10 inches, depending on the nature of the soil. When thinning, it is a good plan to give the ground a thorough hand hoeing. This can be done at a little extra expense and will pay for itself in the long run. If the thinning is put off too long, the crop will suffer.

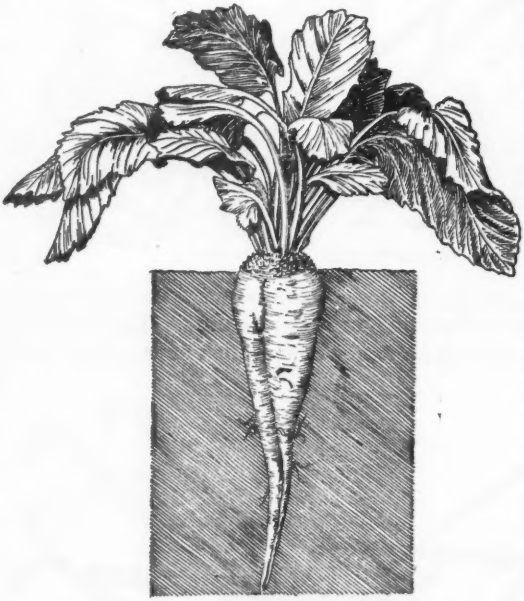

FIG. 13.—Correct position of a mature beet in the soil.

POSITION OF THE BEET IN THE SOIL.

It is important not only that a sugar beet should be of proper size and shape, but also that it be grown in such a manner as to secure the protection of the soil for all of its parts except the top with foliage. The proper position for a beet to occupy in the soil at the end of growth is shown in figure 13. This position can only be secured for the beet by growing it in a soil sufficiently pervious to permit of penetration by the taproot to a great depth. It is for this reason that subsoiling in the preparation of a field for the growth of sugar beets is of such great importance. If the beet, in its growth, should meet a practically

impervious subsoil at the depth of 8 or 10 inches, the taproot will be deflected from its natural course, lateral roots will be developed, the beet will become disfigured and distorted in shape, and the upper portion of it will be pushed out of the ground. Experience has shown that the content of sugar in that portion of a beet which is pushed above the soil is very greatly diminished.

HARVESTING AND DELIVERY OF BEETS.

The time for harvesting varies in different localities. In southern California the beets planted in December are ready for harvesting in the latter part of June or the first of July. In general it may be said that beets planted the first week in May will be ready for harvesting

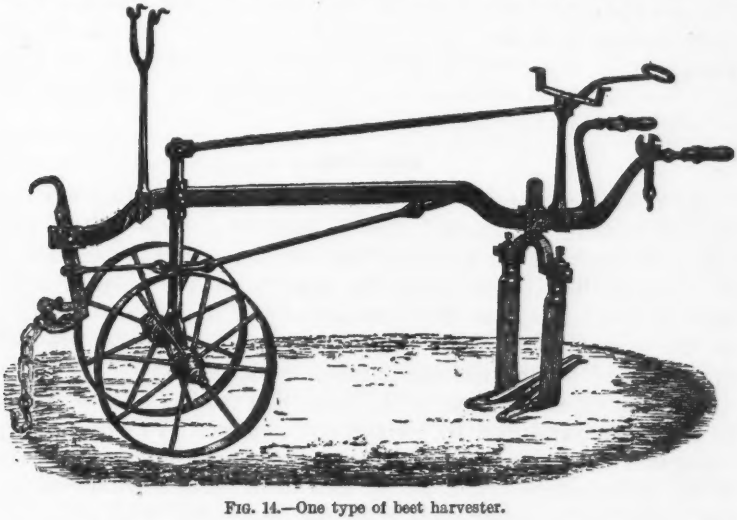

FIG. 14.—One type of beet harvester.

about the 1st of October. Harvesting should be postponed to as late a date as possible, provided the beets are in no danger of a second growth and are not exposed to a freezing temperature. The leaves of the ripened beet change from a rich to a yellowish green, droop and lie close to the earth, and many of them die.

REMOVING BEETS FROM THE GROUND.

The harvesting is easily accomplished by first loosening the beets in the soil and then removing them by hand. For loosening the beets a common turning plow is often used. The edge of the share cuts off the tap roots at the proper depth and the beets are lifted and thrown over by the moldboard. Better adapted to this work, however, are plows which have been specially constructed for beet harvesting. In many localities beets are harvested with an implement such as that

shown in figure 14. It can be used very successfully where rows are perfectly straight and the beets of uniform size. The lifting part of the apparatus runs deep enough in the soil to catch the beet below its middle part. As the "digger" is drawn forward, the beets are caught between its two prongs, which are nearer together in the rear and slope upward; as a result the beets are lifted and the tap roots broken. After the harvester has passed, the beets are lifted out of the ground by means of the leaves.

Several more or less complicated devices have been invented which are designed not only to lift the beets but to cut off the tops and shake off the adhering dirt. Some ambitious inventors have attempted the construction of a harvester which will not only dig, top, and clean the beets, but load them into a wagon. Such a harvester is much to be desired; but while some of these inventions have worked fairly well under favorable conditions, it must be said that none has yet proved satisfactory under all conditions. Hence the use of such harvesters has been very limited.

TOPPING.

The next operation consists in removing from each beet the top or neck bearing the leaves. This is done by a large knife. The object of removing this portion of the beet is to prevent the mineral salts, which have accumulated in large quantities therein, from entering the factory, as they exercise a very deleterious influence on the crystallization of the sugar. The tops and leaves are well fitted for feed or for fertilizing purposes. (See p. 39.)

The removal of the tops of the beets is a tedious process, which in Europe is performed by women and children. In this country sometimes the whole family goes to the beet field and performs the work. More commonly, however, it is done by laborers of various nationalities, who are brought in by the factory and with whom the farmer contracts to do this work as well as the hand work of growing the crop.

The topping of the beets can be a source of great waste for the farmer, as too much may be taken off and the tonnage decreased. Constant supervision is necessary in this work. Several attempts have been made to construct a mechanical device by which the beets can be topped, thus saving a large expense, and perhaps a successful device of this kind may some day be invented. So far as is known at the present time, however, this process has not been successfully accomplished by machinery, and the topping must still be done by hand.

When the beets are topped they are thrown into piles, and the leaves are thrown over them as a protection from the sun or frost until they can be delivered to the factory.

DELIVERING BEETS TO THE FACTORY.

After they are harvested and thrown in piles in the field the beets are usually loaded into wagons and hauled directly to the factory or to a railway station for shipment to the factory. Ordinary farm wagons are often used for this purpose; but wagons specially designed for this work are more satisfactory, and hence are widely used. The bottom and sides of the wagon bed are made of slats with one-half to 1 inch spaces between. As the beets are hauled the shaking and rubbing of the beets tends to free them of adhering soil, which falls out through the cracks. The ends of the wagon bed are stationary and the sides are hinged so as to drop down. These wagons will hold from 3 to 6 tons. A net of rope having from 2 to 3 inch mesh is spread in the wagon first, and on this the beets are thrown. On arrival at the factory the side next the bin is lowered and the projecting net on the other side is fastened to a tackle and raised by power. In this way the load is dumped quickly and with little labor. Sometimes nets are used as a means of lifting beets from ordinary farm wagons.

Where the beets are shipped by rail a special dumping apparatus is installed at the shipping point. The usual form of railroad dump is a high platform approached by a long incline. The loaded wagon is drawn up, the team is unhitched, the wagon locked on the platform, the side dropped, and the platform tipped by machinery. In this way the load is dumped. With another style of dump the wagon is not driven up on a platform, but is left on the ground, the wagon bed being lifted to a height and then dumped.

In cases where there is no railroad dump, a car is placed on a siding and the beets are shoveled into it.

When delivering to the factory, the farmer need not go home with an empty wagon; he can collect manure to be used in fertilizing his fields or can obtain a load of pulp for feed. Most factories, in their contracts with farmers, stipulate that a certain percentage of the weight of the beets delivered can be taken back in the form of pulp. This is a valuable cattle food and the farmer should not miss the opportunity to use it.

TARING.

In shoveling the beets into wagons for delivery to the factory, a certain amount of extraneous matter, such as stems, tops, and clods of dirt, are also thrown in; moreover, certain soils cling to the beets more than others, especially after wet weather. Some deduction must be made from the weight of the load delivered to account for this. Again, the topping may be very poor, not enough being removed, so that there is a loss to the factory, which should be considered. A sample is taken when the load is dumped into the bins

at the factory, the actual percentage of tare is determined, and this figure is applied to the whole load. From the nature of the case, different loads may have a varying percentage of tare, and this point is a constant source of friction between the growers of beets and the factory. But usually it is stipulated in the contract made by the factory with the farmers that the latter may appoint a man to oversee this step in the process.

SILOING SUGAR BEETS.

When beets are to be preserved for manufacture during the winter months or for the production of seed, they must be carefully protected from the deteriorating effect of freezing and thawing. The simplest and the easiest method is to place them in piles and cover them with earth, not too deeply, for if they become too warm in the silo they rapidly lose in sugar content. When first siloed, they should be covered with only a slight layer of earth; as the cold of winter becomes more intense this covering can be increased. In some localities only a slight covering of straw is necessary to protect the beets, as, for instance, in California. In other localities, such as in Michigan and Wisconsin, it is probable that the beets have to be covered to the depth of 6 inches, and even more, to protect them from frost.

It is most important not to put too many beets in one pile, certainly not over 5 tons. If, however, the silo is made in the form of a rick, no such limitation is necessary. There must be an opening in the top to allow ventilation. In case of a rick there may be several. The silo should be placed on the highest point of land available to provide for proper drainage in case of heavy rains or melting snow. The beets should be siloed on the same day that they are removed from the ground.

The object of siloing, in case of beets for seed, is to prevent them from freezing, and greater care should be used in making the silos. In the case of factory beets, the purpose of siloing is not entirely to prevent freezing, for in the frozen state the beets do not deteriorate to any extent; but it is to keep them fresh and prevent their withering or drying out. Freezing and thawing, however, must be avoided, as beets that freeze and thaw a number of times lose a greater part of their sugar by inversion and decomposition.

It is becoming customary in this country for the sugar companies to ask the farmers to silo part of their beets when the total crop can not be worked up before winter sets in. To repay the farmer for this extra handling they are given a sum varying from 20 cents to 50 cents a ton extra. A few factories situated in the cooler regions where siloing must be practiced agree to take all of the beets of the farmer before frost comes and silo them, but this is not the

general practice. In California very little siloing has to be done, and then only by using the leaves as a covering.

COST AND PROFITS OF GROWING SUGAR BEETS.

The cost of growing an acre of beets depends on so many varying factors as to render it impossible to give an estimate which is reliable for every locality. The differences in rent of land, cost of labor, methods of culture, etc., require that any estimate which may be given should be revised for almost every series of conditions. The following estimate of the cost per acre, made several years ago when wages were somewhat lower than at present, is based on a yield of 12 tons per acre, except in Utah, where the yield was placed at 15 tons.

An assumed yield per acre is requisite in estimating the cost of harvesting, etc., since a part of the cultivation and the harvesting are often contracted at a certain price per ton of beets. The figures given below are from actual averages or from estimates by experienced men.

Estimated cost per acre of sugar-beet culture.

Items.	California.	Utah.	Nebraska.	Michigan.
Clearing the land			$1.00 to $1.50	$2.25
Plowing and harrowing	$5.37	$3.50	2.50 to 3.00	
Seed and seeding	1.80	2.75	3.25 to 3.85	2.50
Bunching and thinning	14.40	4.00	7.00	7.00
Hoeing		4.00	2.00 to 4.00	4.00
Cultivating		2.00	1.50 to 1.60	1.50
Other expenses		[a] 1.50		
Harvesting and delivering	[b] 1.50	[c] 15.00	11.00 to 13.20	17.20
Total	23.07	32.75	28.25 to 34.15	34.45
Cost of siloing when necessary			2.50 to 8.00	

[a] Cost of irrigation. [b] Exclusive of delivery. [c] Based on a yield of 15 tons per acre.

In the above estimate was included the cost of the best culture, but nothing for rent of land or a reasonable application of fertilizers. It is probable that the actual cost to our farmers for the first few years of the beet industry did not exceed $25 to $35 per acre and in many instances fell below these figures.

It is reasonably certain, accidents of season aside, that a net profit of from $8 to $15 per acre may be expected from the proper culture of the sugar beet in localities near a factory when all the conditions of the best methods of culture are fulfilled.

For comparison with the above estimate there are given in the following table the actual figures submitted by a Colorado farmer, as published in The American Sugar Industry and Beet Sugar Gazette of June 20, 1907, and also those given by a Wisconsin farmer and a Washington farmer in the same journal for April, 1908.

Reported cost of sugar-beet culture in three actual cases, and the net returns.

Items.	Colorado.	Wisconsin.	Washington.
Number of acres planted	5	11	11
Plowing, harrowing, leveling	$8.75	$34.85	$24.00
Seed	$12.30	$39.00	$26.70
Drilling	$2.25	$6.40	$4.00
Thinning	$22.75	$60.00	$66.00
Hoeing	$10.25		$30.50
Cultivating and ditching	$9.00	$27.50	$17.50
Irrigating	$3.50		
Total cost	$71.05	$167.75	$168.70
Average cost per acre	$14.21	$15.25	$15.34
Cost of harvesting and delivery		$218.00	$133.15
Total average cost per acre	$27.00	$35.07	$27.44
Number of tons of beets harvested		135	115
Amount received for beets		$695.00	$607.00
Average receipts per acre		$63.18	$55.18
Net returns per acre		$28.11	$27.74

In none of these estimates have the rent of the land or interest on capital been considered. It is not wise to underestimate the actual cost of growing the beets, for this will lead the farmer to expect large profits, which often in practice give way to actual deficits.

VALUATION OF BEETS AT THE FACTORY.

In the purchase of beets for sugar making the factories offer the growers either a "flat rate" or a "sliding scale." In case the former system is adopted, the factory offers a uniform price of $4.50 or $5 per ton for all beets which reach or exceed a certain minimum standard of quality, as, for instance, a sugar content of 12 or 14 per cent with a purity of 80. In case beets which fall below this standard are offered, the factory may make a reduction in the price or refuse the beets, but no extra price is paid for beets which exceed the standard requirements. If the "sliding scale" is adopted, the factory offers a minimum price of say $4 or $4.25 for beets which reach a minimum standard of quality, as, for instance, 12 per cent of sugar with a purity of 80, and makes an extra allowance per ton of 25 to 35 cents for each per cent of sugar in excess of the established minimum. Under this system beets of extra fine quality may bring $5.50 per ton or even more. Some factories buy all their beets at a flat rate, others buy only according to a sliding scale, while many offer the farmers their choice between the two systems.

In determining the quality of the beets a sample is taken from each load delivered. The percentage of sugar is determined either directly from the beet or from the expressed juice. If from the juice (which is the usual method), the percentage of sugar in the beet is calculated from that in the juice.

According to a United States Census report on the manufacture of beet sugar in 1905, the average prices paid for beets were as follows:

Prices per ton paid for beets in 1900 and 1905 compared.

State.	1905.	1900.
	Dollars.	*Dollars.*
Colorado	5.28	.....
Michigan	5.52	4.38
California	4.72	4.47
Wisconsin	5.36	.....
All other States	5.19	4.26
Average for the United States	5.22	4.39

A comparison of these figures shows that there was a large increase in the price of beets during this five-year period.

BEET-SEED PROBLEMS.

PRODUCTION OF SEED.

The production of seed is one of the most important operations connected with the sugar-beet industry. On the care and skill which are displayed in this process depend the improvement and maintenance of the sugar-producing qualities of the beet. It is, however, an industry in itself and only the result is of practical interest to the average farmer. There are many different methods employed for producing seed which will grow the richest sugar beets, but there will be given here only a general outline of the principles which underlie the process. The beets which are to be preserved for seed are called "mothers" and are selected at the time of harvesting from specially grown beets or from fields of beets which have shown particularly good qualities on analysis. The size of the roots selected for mothers is about the average for the best sugar beets, viz, from 20 to 24 ounces. Smaller beets than these might show a higher content of sugar, but it is not wise to produce a race of small beets. The weight of the mothers having been decided upon, the beets are next selected for their shape and external appearance. Those regular in shape and smooth in external form are to be preferred.

The beets to be preserved for mothers are harvested with the greatest care to avoid injury. The top is not cut away, but the leaves are removed by cutting off the stems without injuring the top of the beet.

They should be siloed in such a way as to protect the beets entirely from frost and yet prevent their growth in the silo until the spring. The beets are removed from the silo at an early date in the spring and are immediately subjected to analysis. The final selection depends upon actually determining the density of the juice and its content of sugar. For this purpose a cylindrical piece of the beet is removed

by an appropriate instrument cutting diagonally through the center of the root. This piece may weigh one-half ounce or even more, and its removal does not injure the beet for seed-bearing purposes. The juice is expressed from this piece and its specific gravity determined, as well as the percentage of sugar in the juice. From the specific gravity the amount of solid matter in the juice can be calculated. The percentage of sugar is determined by means of the polariscope.

From these data the quality of the beet is ascertained and the question as to its use as a mother for seed is determined. An important figure in this work is the ratio of sugar to total solids in the beet; that is, the sugar divided by the total solids, the quotient being multiplied by 100. This figure is spoken of as the "coefficient of purity."

The procedure for selecting beets where seed is produced on a commercial scale is in brief as follows: A standard is set for sugar content and also for purity. The beets are analyzed separately and are divided into two classes, namely, those in which either the content of sugar or the purity falls below the fixed figure, and, second, those in which these two numbers equal or exceed the fixed figures. It is sometimes customary to divide the latter class into two portions, viz, those roots in which the numbers equal or slightly exceed the standard, and, second, those which show exceptional richness. It is also customary to number each beet, and the number, which is cut into the skin of the beet, will remain legible even after the seed has ripened. Some of the producers of sugar-beet seed preserve the product of seed from each beet by itself, and do not use it to inaugurate the production of seed for commerce until it has received an additional year's trial.

Many seed producers determine the percentage of sugar in the beet by a direct analysis of a pulped sample and base the selection of the mothers on the number so obtained, without regard to the coefficient of purity, as it has been proven in Germany that a beet of a certain sugar content will under most circumstances have a certain purity.

By careful selection of mother beets and scientific culture the sugar beet has been raised to its present high standard of excellence, and is only maintained at this standard by constant supervision, such as has been indicated.

DOMESTIC PRODUCTION OF BEET SEED.

The commercial production of beet seed of pure pedigree and high grade has not been practiced to any great extent in this country. Beet seed has been grown for a number of years in the State of Washington and also in Utah. The latter State consumes its own crop, while the seed from Washington has been used in all the beet-growing States. In 1904 the Department of Agriculture distributed 13,962 pounds of American-grown sugar-beet seed, the greater part coming

from Washington. This seed went to farmers growing beets for factories, and therefore was tested in direct comparison with the factory seed which is practically always imported. It was tested on 153 farms, representing thirteen different States, 564 acres being planted. The results gave an average yield for Washington-grown seed of 10.72 tons per acre, against 9.92 tons harvested from an equal area raised from imported seed.

To grow sugar-beet seed commercially certain conditions must exist which are not always applicable to experimental work. It is necessary not only that seed of high quality be grown, but also that it be grown economically and that there be reasonable certainty of a crop. Climatic conditions, such as the probability of severe rainfall at the time of harvesting, play an important part in selecting a location for a beet-seed farm. The prevalence of insects and other pests must also be considered.

COMPARATIVE VALUE OF DOMESTIC AND FOREIGN SEED.

Numerous comparisons of home-grown and imported beet seed have been made. The plants from the native-grown seed seem to have a higher vitality and to be better suited to the climatic conditions of the locality than those grown from imported seeds. They show during the growing season a more abundant foliage and a better development of roots. This higher vitality and quality of the beets grown from domestic seed illustrate in a forcible degree the advisability of the production of our beet seed at home. Even granting that seeds produced in foreign countries have the same high qualities, it must be admitted that their vitality is in danger of being very much diminished during shipment to this country. The moist air in the holds of ships in which they are transported often produces moldiness and incipient germination, which tend to diminish their value greatly. In 1904 American-grown seed yielded 10.72 tons of beets per acre with a sugar content of 15.41 per cent, while imported seed averaged 9.92 tons with 15.26 per cent of sugar, the excess of sugar from the use of American-grown seed being from 300 to 350 pounds per acre. In 1905 American-grown seed yielded 14.32 tons of beets per acre with 14.9 per cent of sugar, while imported seed averaged 12.14 tons with 15.1 per cent of sugar, an excess of more than 600 pounds of sugar per acre of beets. In 1905 the averages were taken from 278 acres. These data should be carefully studied by all those who are interested in the production of beet sugar in this country. At present there is one grower of beet seed on a large commercial scale, and it is certain that it will not be long before there will be a demand for the establishment in this country of more plantations devoted exclusively to the production of beet seed on the most approved scientific principles.

The quantity of seed required to plant an acre is about 15 pounds. The approximate number of acres planted to beets in this country during the season of 1907 was 400,000, requiring 6,000,000 pounds of seed. More than 6,500,000 pounds of seed were required for the crop of 1908. It is evident that there is already an opportunity for the active operation of large plantations devoted exclusively to the production of beet seed for domestic use.

Another point to be considered is that by the importation of foreign seeds there is danger of introducing those diseases of beets which have occasioned such ravages in Europe.

SINGLE-GERM BEET SEED.

The average beet-seed ball contains from 1 to 7 germs or seeds, each capable under certain conditions of producing a plant. In practice some seed balls will produce as high as seven plants, while others will only produce one. The Bureau of Plant Industry of the Department of Agriculture has undertaken the development of a strain of sugar beets bearing single-germ seed balls, and the results of that work up to 1905 have been published in a bulletin of that Bureau (No. 73). By careful selection, plants bearing 50 per cent of single-germ seeds have been produced. It is confidently expected that in time a plant bearing only single-germ seeds will be produced. The economy in the use of such seed is evident, as, when planted in a row, the thinning can be done by means of a hoe, thus doing away with hand thinning. This work was undertaken in 1902, and up to the present time is still in an experimental stage, none of this seed being available for distribution.

DISEASES AND INSECTS AFFECTING THE SUGAR BEET.

There are three diseases of the beet which prove especially destructive: One is the "leaf spot" due to a fungus (*Cercospora beticola*), in which the leaves are covered with brown spots and die, forcing the beet to throw out new leaves at the expense of the sugar content and growth of the root. This has been successfully combated on a small scale by spraying with Bordeaux mixture, but whether this can be done economically on a commercial scale is still under investigation. The second disease, "root rot," likewise due to a fungus (Rhizoctonia), in which the roots finally rot off, seems to be increasing. If attended to in time, it can be checked by the use of air-slaked lime. The lime is sprinkled broadcast over the infected area and thoroughly hoed into the soil. The third disease, known as "curly top," causes the leaves to curl up; the beet does not develop, but finally dies. No satisfactory means of combating this disease has so far been devised, but reports on the subject have been issued by

the Bureau of Plant Industry and the Bureau of Entomology of the Department of Agriculture.[a]

A number of other diseases, including "crown rot" and "damping off," have been studied, but they are confined to small particular areas and have not wrought the damage that follows the three especially mentioned.

Many species of insects use beets as food. Not more than about 50 species, however, are classed as noticeably destructive to the crop. Many of these have received extended notice in publications of the Bureau of Entomology[b] of the Department of Agriculture. From these reports the farmer can learn what has been done along this line and obtain suggestions as to the means of fighting the pests.

The beet growers should send specimens of insects injurious to their crops direct to the Bureau of Entomology for specific identification and advice as to remedies.

THE MANUFACTURE OF SUGAR.

THE FACTORY PROCESS.

The process of making sugar from the sugar beet is only of secondary interest to the farmer, and will be treated as briefly as possible, giving merely an intelligent general idea of the methods followed. The beets are stored in bins which narrow down to a flume covered by small boards. By removing the boards, one at a time, the beets are fed into the flume, where a swift running stream of water carries them to a wheel or screw that lifts them to a washing tank. This is provided with an apparatus for keeping the beets in motion and transferring them toward the end from which the fresh water enters. In this process the whole of the adhering soil, together with any sand and pebbles, is completely removed. By a suitable elevator the beets are next taken to a point above the diffusion battery, where they pass into automatic scales, which dump them when a certain weight has been received. From this they are dropped into a slicing apparatus, by which they are cut into thin pieces, called "cossettes," of greater or less length, and of such a shape that when placed in the cells of the battery they will not lie so closely together as to prevent the circulation of the diffusion liquors. When the cell is full of the sliced beets it is closed and the hot juices from the cell last filled are admitted and allowed to remain in contact with the cuttings for a few minutes. From 10 to 12 cells are thus kept in use. While one is filling another is emptying. The fresh hot water is

[a] U. S. Dept. Agr., Bureau of Plant Industry, Bul. 122; Bureau of Entomology, Bul. 66, Part IV.

[b] A Brief Account of the Principal Insect Enemies of the Sugar Beet, Bul. 43, Bur. of Ent., U. S. Dept. of Agr. Reference is also made to insects of this class in Buls. 23, 29, 33, 54, 63, and 82 of the same series

always admitted to the cell next to be emptied and passes in succession through all the cells under pressure, until it reaches the one last filled. From this cell a quantity of juice is drawn off each time and sent to the carbonatation tanks for purification. With the drawing

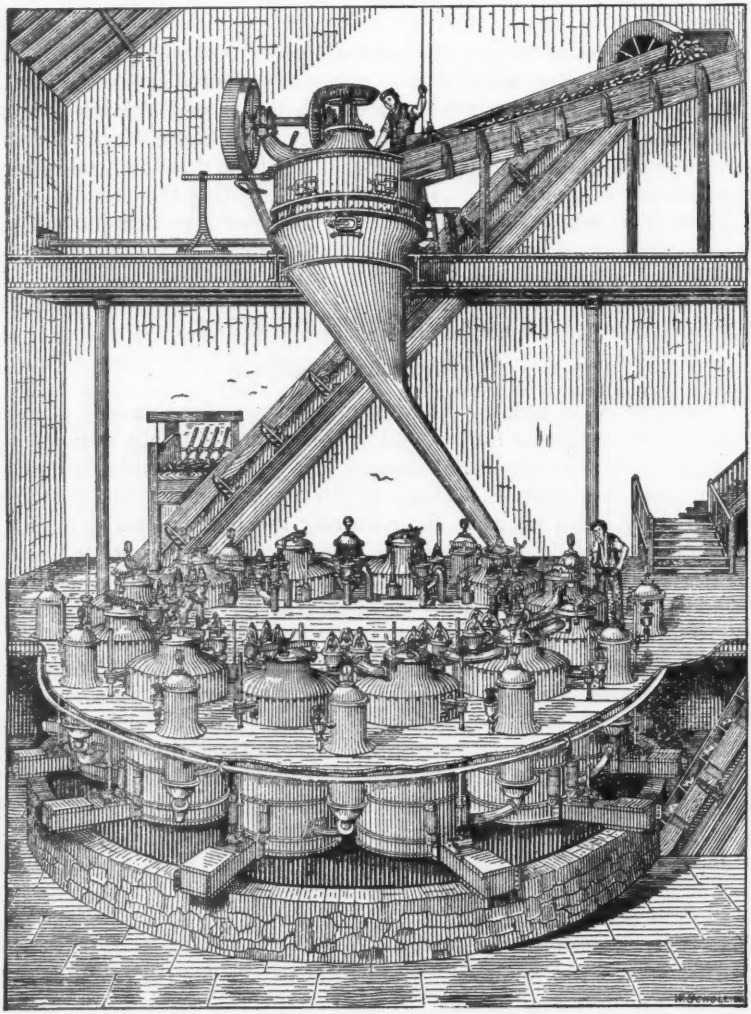

FIG. 15.—Diffusion battery.

off of a certain quantity of the juice, one cell of exhausted beet pulp, the last one in the circuit, is dumped. Figure 15 illustrates in a general way the arrangement of a diffusion battery, but the circular type

there shown is no longer in use, the cells now being arranged in a straight line.

The extracted cuttings are carried by conveyers to a press, where a portion of the water is removed, and they are then "scrolled" out to a silo in suitable condition for use as cattle food. The diffusion juice obtained as above described is conveyed to carbonatation tanks, where it is treated with from 2 to 3 per cent of its weight of lime in the form of a thick milk. The whole is heated and carbonic acid gas (obtained from the limekiln) is pumped into the mixture until a certain alkalinity of the juice is obtained. By this process the impurities in the diffusion juice are to a great extent thrown out and some of the extra lime precipitated also.

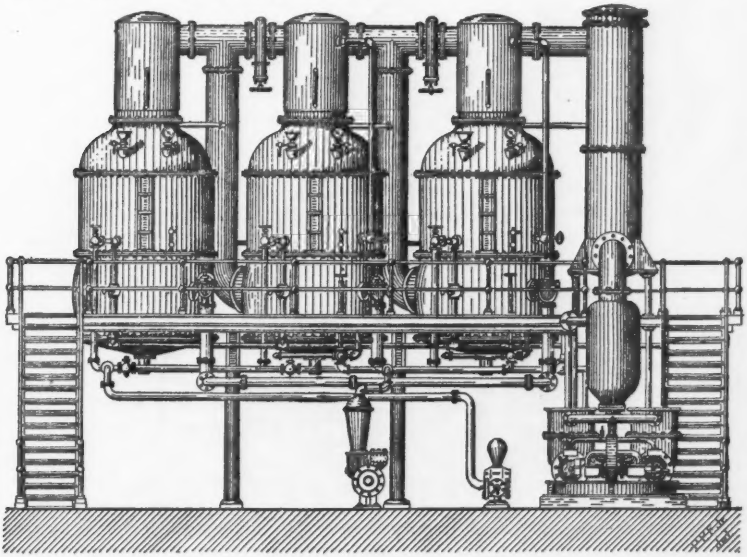

FIG. 16.—Multiple-effect evaporating apparatus.

The slightly alkaline juice is next passed through filter presses, by which the precipitated lime and other solid matters are removed. The juice from these filters then passes to a second set of carbonatation tanks, in which they undergo a treatment similar to that just mentioned, but the quantity of lime added is small as compared with that of the first carbonatation. The refiltered juices from the second carbonatation, usually termed the "saturation," are then sent to tanks, through which the fumes of burning sulphur or sulphur dioxid are passed. This treatment removes more lime and impurities besides lightening the color of the juice. From these tanks the juice goes to another set of filters, generally composed of bags, and from there to storage tanks for the multiple-effect evaporators.

The multiple-effect evaporating apparatus (fig. 16) consists of a series of pans connected in such a manner as to secure a progressively higher vacuum. The thin juices enter the first pan, where they may be evaporated, either under slight pressure or in a vacuum. The steam with which this evaporation is effected is usually the waste coming from the engines and pumps of the factory.

The vapors generated in the first pan enter the heating pipes of the second one, and are thus utilized in evaporating the somewhat concentrated sirup which is drawn off from the first pan into the second one, where the vacuum is higher, being represented by a column of mercury of from 12 to 15 inches in height. The vapors which are produced in

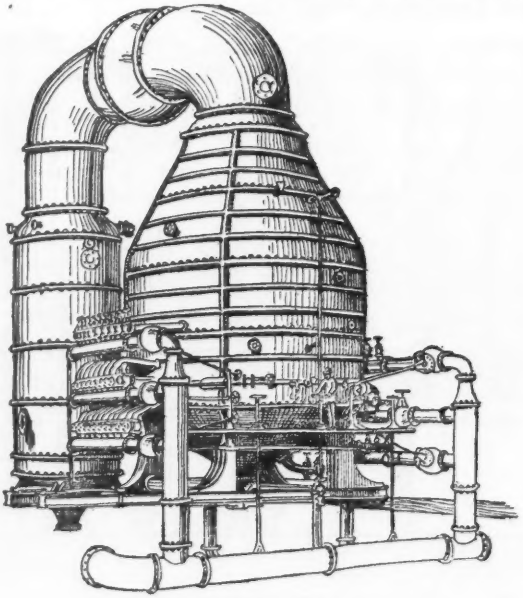

FIG. 17.—Vacuum strike pan.

the second pan are in like manner conveyed to the heating pipes of a third apparatus, where the still more concentrated sirups from the second pan are conducted and evaporated at the highest vacuum obtainable in such apparatus, usually from 26 to 28 inches of mercury. Usually a fourth pan is employed, but the arrangement is fully illustrated by the above example. It is easy to see by the arrangement above noted that the evaporation of the thin diffusion juices to a heavy sirup is accomplished with the greatest economy, direct steam being admitted only into the first pan, and the rest of the operation being accomplished by the steam generated in the evaporation of the liquors. The thickened juice from the last effect of the multiple

evaporator is sent to tanks where it is again treated with lime, phosphoric acid, and soda to remove impurities, and also with sulphur dioxid to lighten the color. From here it passes to bag filters and then into storage tanks. This juice is converted into sugar in the following manner:

A portion of the sirup is placed in an evaporating apparatus called the strike pan. This apparatus is very large, usually a cylindrical vessel with a conical bottom, and is provided with a series of coils, one above the other, to which the steam can be admitted at will. The admission of steam is always so regulated that it is not allowed to enter any of the coils above the surface of the liquid in the pan. The

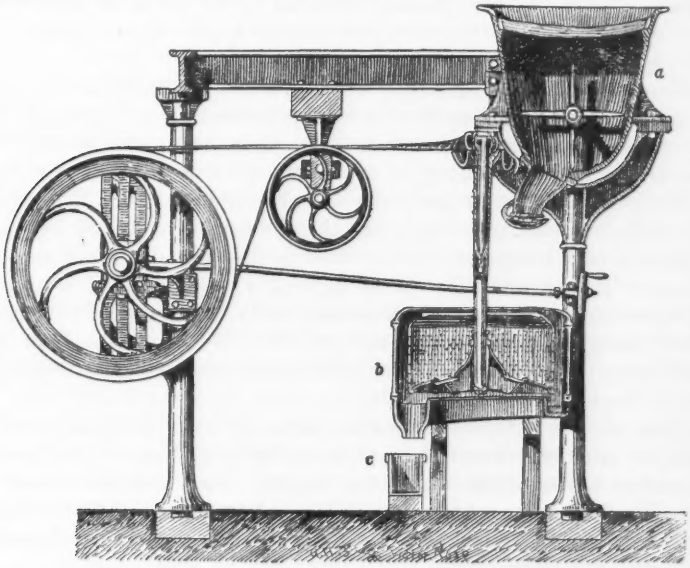

FIG. 18.—Centrifugal apparatus: *a* holder for massecuite; *b* centrifugal basket with fine wire lining *c* molasses trough.

portion of sirup first introduced is evaporated until it reaches a point of consistency which will permit of the formation of crystals, i. e., supersaturation. In this condition, if a portion of fresh sirup be introduced the whole mass in the pan becomes charged with exceedingly fine crystals of sugar.

By careful manipulation and the introduction of new quantities of sirup from time to time these crystals are made to grow. As the pan becomes full successive coils of the steam pipes are brought into use, so that the boiling surface of the pan is gradually increased in proportion to the volume of its contents. In the course of a few hours the skilled sugar boiler will find that the pan is full and that the crystals

have grown to the proper size. The charge in the vacuum pan at this stage is extremely heavy, consisting of a dense mass of sugar crystals mixed with a quantity of molasses which varies in amount with the purity of the juices from which the sugar is made. This product is termed massecuite. The illustration (fig. 17) shows the vacuum pan. In boiling sugar in a vacuum pan, if the highest possible yield is desired and no objection arises to the formation of soft crystals, a very high vacuum, equivalent to 29 inches of mercury at the sea level, is employed. At this vacuum the sirups boil at a temperature of from 112° to 120° F. If harder crystals, giving a somewhat less yield are desired, as in the case of making granulated sugars, a lower vacuum, namely, from 24 to 26 inches, is employed.

The massecuite is then dropped directly to the mixer, where it is stored for charging the centrifugals below it.

The construction of the centrifugal apparatus and mixer is shown in figure 18. The centrifugal basket is suspended and run by the spindle. The whole basket is incased in an armor-plate jacket and is lined with fine wire gauze. The charge of massecuite is let down into the basket, which is revolved by means of the belt at a speed of about 1,200 revolutions per minute. At this speed the molasses is separated from the sugar crystals, being thrown out through the holes of the screen onto the outer jacket, where it collects and finally runs through the trough, provided for the purpose, to the storage tank. The color of the charge is now changed from brown to light yellow. By a sprinkling can or a small spray of water the rest of the molasses in the fast running centrifugal is washed off of the crystals.

From the centrifugals the sugar passes by belts and conveyers to bins for storage. From these it is carefully and slowly fed into a heated revolving drum where the sugar is dried and the masses of individual crystals are broken up. This is termed granulation. From this point the sugar passes to weighing machines where it is barreled or sacked for commerce.

The resulting molasses is still rich in sugar and is brought back to the vacuum pan where it is boiled to a massecuite which is placed in large double-jacketed tanks having a revolving worm. The double jacket is filled with heated water and the massecuite is allowed to stay in the tank for a number of days, being mixed by the revolving arm. The temperature is allowed to fall slowly and by this means more crystals of sugar are formed. When no more of the sugar will crystallize, the tank or "crystallizer" is emptied into another set of centrifugals and the sugar is spun off. This crop is generally very dark in color and washing does not lighten it to a white sugar. It is known

as second sugar and is melted in water and boiled up with the juice from the evaporator in the vacuum pan to make white sugar. In its raw state it is not the same as the yellow sugar of commerce, being generally salty and disagreeable in taste. The resultant molasses is sometimes boiled for a third crop of sugar, but generally it is sent to storage or is used in the osmose or Steffens process for removing more sugar from the molasses.

In the osmose process a stream of heated, diluted molasses is run in a suitable press in the opposite direction to a stream of hot water, a sheet of parchment paper separating the two streams. By this means a greater portion of the salts passes through the membrane and enters the water which flows away. The sirup is made richer, and by boiling in the evaporator and in the pan a massecuite is formed that is stored in crystallizers, and finally the sugar is spun off. The remaining molasses is sometimes reosmosed, but generally it is sold to be mixed with pulp or grain for cattle food or is used for alcohol making.

In the Steffens process the molasses is diluted and cooled to a low temperature, which is kept constant while finely powdered fresh lime is added slowly. In this way a saccharate of lime is formed which is insoluble in the liquid, and by passing the whole material through filter presses it is separated. The cake from the presses is diluted with water and takes the place of the milk of lime used in the carbonation. When this process is employed there is no residue molasses; the only waste is the strongly alkaline water containing the salts of the molasses which have been separated from the saccharate of lime. This water is rich in potash salts and could be used as a fertilizer.

The beet-sugar factories of this country sell only the white granulated sugar; none of them produce raw sugar and turn it over to the refineries to be passed over bone black and made into white sugar, as is the custom in Europe.

COST OF MANUFACTURE.

The cost of manufacture depends on as many factors as that of beet growing. Chief among these are transportation, fuel, weather, and labor. Perhaps the most important of these factors is the price of fuel. In some localities coal can be had for $1.25 per ton; in others the cost may reach as high as $10 per ton.

The manufacture of beet sugar is conducted without governmental supervision in this country, and any exact account of its cost is inaccessible. To show what it may be, when a wide experience and the best management are brought to bear upon the work, the mean cost of manufacture in 113 German factories is given.

Mean capital invested in each factory		$193,400.00
Total receipts for sugar, molasses, and pulp per ton of beets		11.10
Mean cost of beets per ton of 2,204.62 pounds	$4.90	
Salaries per ton of beets	.26	
Labor per ton of beets	.73	
Interest on investment per ton of beets	.36	
Coal per ton of beets	.63	
Miscellaneous expenses per ton of beets	.96	
Total expense of manufacture per ton		7.84
Profit per ton of beets		3.26

The mean net profit for each factory was $34,240. The price paid for beets, however, is in most cases fictitious, the beet growers owning the factory and preferring to share in the general profits rather than to charge a high price for the beets. First-class beets rarely sell for less than $5 per ton. The Western Beet Sugar Company, of Watsonville, Cal., stated that in its first campaign, 1888–89, the cost of manufacture amounted to $80.80 per ton of sugar. At the present time it appears that with the best machinery, rich beets, and most economical processes beet sugar can be made in this country at a cost of less than 4 cents per pound, even when the price of rich beets exceeds $5 a ton.

COST AND CAPACITY OF FACTORIES.

The cost of building a first-class beet-sugar factory is much greater than is commonly supposed. Roughly speaking, for every ton of daily capacity, the plant costs $1,000; that is, a 500-ton plant would cost $500,000 and a 1,000-ton factory would cost $1,000,000. It has been demonstrated in the United States that a beet-sugar mill, in order to work economically, must have a capacity to work 500 tons of beets daily, and that one having a capacity of much more than 1,200 or 1,500 tons a day is unwieldy. The largest factory in the United States can handle 3,000 tons a day. In Germany there are a few small factories of 200 and 300 tons capacity, but the tendency of late has been to increase the size. In the early days of the beet-sugar industry in this country, Europe was called on to furnish all machinery. Now, very little is imported, and, in fact, some of the foreign factories are using American-made machinery.

COOPERATIVE FACTORIES.

It is seen from the foregoing paragraph that the farmer can have no reasonable hope of successfully establishing a home beet-sugar factory. It is not just, however, that he should be deprived of any cooperation in the process of manufacture or a reasonable share of the profits arising therefrom. The methods which have been practiced in Europe for securing these results may eventually come into use in this country. The cooperative sugar factory, in which the farmers growing the

beets hold a part or a majority of the stock, realizes the desired end. The growers of beets holding shares in the factory have a greater interest in its prosperity and try to grow better crops and to secure in every way a higher yield. The cooperative factory renders impossible those disagreements between factory and agriculture which do so much to retard the progress of the industry and to embitter the farmers against the factory. To show the extent of the participation of shareholders in factories in the growing of beets in Germany, it may be stated that of the 11,672,816 metric tons of beets delivered to the German factories in 1895–96, 2,689,004 tons were grown by shareholders. As long as the proprietors of the factory and the farmers growing the beets are satisfied with the contracts which they make, there is no urgent necessity for the establishment of cooperative enterprises. When the number of beet-sugar factories in this country, however, begins to reach the hundreds, favorable opportunities for cooperative establishments will be presented.

USES OF BY-PRODUCTS.

The by-products from beet culture on the farm are the tops and leaves, which are commonly used for feeding cattle. Some farmers, however, turn them under as a fertilizer. When used as a feed, the beet tops can be eaten by the cattle on the field where they have been grown. If they are fed in stalls, the manure should be returned to the field.

The by-products of the factory consist of pulp, lime cake, and molasses. The pulp is a valuable cattle food and the farmer should contract with the sugar company to obtain his share of it. It can be stored in siloes, if well drained, and be fed fresh or in a fermented condition. The value of the pulp for feeding purposes is variously estimated at from one-fifth to one-third the value of the beets. Its sugar content is not sufficient to make it of any value as a source for alcohol manufacture. Lime cake in most factories is washed out with water to the sewer. In others it is wheeled out and dumped in piles and can be used on some lands as a fertilizer, though for this purpose the demand for it is limited. Lately it has been used in cement making. Molasses has a value as a cattle food, but it must not be fed very heavily or scouring of the cattle will result. The best practice is to sprinkle it on the hay, alfalfa, or roughage. Some factories mix the molasses with the pulp and dry the whole, either pressing it into bricks or selling it loose. With the increased installation of the Steffens process of desugarizing molasses, there is not so much molasses resulting from beet-sugar manufacture as was obtained a few years ago. In an economical plant all molasses should go through this process and only that produced at the end of the season be saved. It is a question whether the introduction of denatured alcohol into the

arts, as well as for fuel and light, will not tend to reduce the number of Steffens plants and result in the sale of the molasses for distillation. Beet molasses contains about 50 per cent of sugars capable of fermentation. One gallon weighing about 12 pounds contains approximately 6 pounds of sugar, which will produce about 3 pints of 95 per cent alcohol. In other words, for every 2½ gallons of molasses 1 gallon of alcohol can be made.

STATISTICS OF PRODUCTION AND CONSUMPTION OF SUGAR.

In the data giving the production and consumption of sugar the unit of value commonly employed is the ton. By reason of the fact that the ton in this country expresses a unit of varying magnitude a considerable degree of confusion is often introduced into statistical tables. In the following tables the kind of ton used is specified in each case. The long ton, which is often used in compiling sugar statistics, contains 2,240 pounds. The short ton, namely, 2,000 pounds, is a more convenient unit of expression, and is largely used in the publication of sugar statistical data in this country. The metric ton, which is used on the continent of Europe, is a weight of 1,000 kilograms, equivalent to 2,204.62 pounds.

BEET-SUGAR PLANTS IN THE UNITED STATES.[a]

The following table gives a complete list of beet-sugar plants in the United States, arranged by States, showing the official names of the manufacturing companies and the locations of the factories. It also shows the daily slicing capacity, expressed in tons of beets, for each factory, the combined daily slicing capacity of the factories in each State, and the aggregate capacity of all the factories in the United States.

Beet-sugar companies and factories of the United States.

Manufacturing companies.	Factory locations.	Number of factories.	Daily slicing capacity.
			Tons of beets.
Arizona:			
Southwestern Sugar and Land Co., main office, Phoenix.	Glendale	1	800
California:			
Alameda Sugar Co.	Alvarado		800
Los Alamitos Sugar Co.	Los Alamitos		700
Spreckels Sugar Co.	Spreckels		3,000
Union Sugar Co.	Betteravia		1,000
American Beet Sugar Co., main office, 32 Nassau street, New York; Pacific coast office, 16 California street, San Francisco.	Chino		900
	Oxnard		2,000
Pacific Sugar Corporation, main office, Corcoran, Cal.	Visalia		400
	Corcoran		600
Sacramento Valley Sugar Co.	Hamilton City		700
Southern California Sugar Co.	Santa Ana		600
Total		10	10,700
Colorado:			
American Beet Sugar Co., 1530 Sixteenth street, Denver, Colo.	Rocky Ford		1,000
	Lamar		400
	Las Animas		700

[a] The American Sugar Industry and Beet Sugar Gazette, May, 1910.

Beet-sugar companies and factories of the United States—Continued.

Manufacturing companies.	Factory locations.	Number of factories.	Daily slicing capacity.
Colorado—Continued.			*Tons of beets.*
Holly Sugar Co.	Holly		600
	Swink		1,200
National Sugar Manufacturing Co.	Sugar City		500
The Great Western Sugar Co., general offices, Sugar Building, Denver, Colo.	Eaton		600
	Greeley		600
	Loveland		1,200
	New Windsor		600
	Longmont		1,200
	Fort Collins		1,200
	Sterling		600
	Brush		600
	Fort Morgan		600
The Western Sugar and Land Co.	Grand Junction		600
Total		16	12,200
Idaho:			
Utah-Idaho Sugar Co., main office, Salt Lake City, Utah.	Idaho Falls		1,200
	Sugar		1,200
	Blackfoot		600
	Nampa		750
Total		4	3,750
Illinois:			
Chas. Pope, Chicago, Ill.	Riverdale	1	350
Iowa:			
Iowa Sugar Co.	Waverly	1	500
Kansas:			
United States Sugar and Land Co.	Garden City	1	850
Michigan:			
Michigan Sugar Co., general offices, Saginaw, Mich.	Bay City		600
	Caro		1,200
	Alma		750
	Carrollton		800
	Sebewaing		600
	Croswell		600
West Bay City Sugar Co.	Bay City, West Side		600
Holland Sugar Co.	Holland		350
Owosso Sugar Co., main office, Bay City, Mich.	Owosso		1,200
	Lansing		600
German-American Sugar Co.	Bay City, Station A		650
Mt. Clemens Sugar Co.	Mt. Clemens		600
Menominee River Sugar Co.	Menominee		1,200
St. Louis Sugar Co.	St. Louis		600
The Continental Sugar Co., main office, Cleveland, Ohio.	Blissfield		600
West Michigan Sugar Co.	Charlevoix		600
Total		16	11,550
Minnesota:			
Carver County Sugar Co.	Chaska	1	600
Montana:			
The Great Western Sugar Co.	Billings	1	1,200
Nebraska:			
American Beet Sugar Co.	Grand Island	1	350
New York:			
Lyons Beet Sugar Refining Co.	Lyons	1	600
Ohio:			
Continental Sugar Co., main office, Cleveland, Ohio.	Fremont	1	400
Oregon:			
Amalgamated Sugar Co.	La Grande	1	400
Utah:			
Amalgamated Sugar Co., office, Ogden, Utah.	Logan		600
	Ogden		400
	Lewiston		600
Utah-Idaho Sugar Co., main office, Salt Lake City, Utah.	Lehi[a]		1,200
	Garland		1,200
Total		5	4,000
Washington:			
Washington State Sugar Co., main office, Spokane, Wash.	Waverly	1	500
Wisconsin:			
Wisconsin Sugar Co., main office, Milwaukee, Wis.	Menomonee Falls		500
Chippewa Sugar Co., main office, Milwaukee, Wis.	Chippewa Falls		600
Rock County Sugar Co.	Janesville		600
United States Sugar Co.	Madison		600
Total		4	2,300
Grand total		66	51,050

[a] Slicing stations at Springville, Spanish Fork, and Provo.

BEET-SUGAR PRODUCTION IN THE UNITED STATES, 1830-1909.

The following table shows the production of beet sugar in the United States from the beginning of the industry to the close of the season of 1909. The data for 1897 and for 1901–1909 are from reports published by the United States Department of Agriculture on Progress of the Beet-Sugar Industry in the United States. Figures for other years are from Willett & Gray. (See Yearbook, U. S. Department of Agriculture, 1909, pp. 543, 544.)

Beet sugar produced in the United States, 1830–1909. [a]

1830	A few hundred pounds	1891	5,356 tons
1831–1837	None	1892	12,018 tons
1838–39	1,300 pounds	1893	19,950 tons
1839–1862	None	1894	20,092 tons
1863–1871	300 to 500 tons per annum	1895	29,220 tons
1872	500 tons	1896	37,536 tons
1873	700 tons	1897	40,398 tons
1874–1877	Under 100 tons per annum	1898	32,471 tons
1878	200 tons	1899	72,944 tons
1879	1,200 tons	1900	76,859 tons
1880	500 tons	1901	164,827 tons
1881–82	Less than 500 tons	1902	194,782 tons
1883	535 tons	1903	214,825 tons
1884	953 tons	1904	216,173 tons
1885	600 tons	1905	279,393 tons
1886	800 tons	1906	431,796 tons
1887	255 tons	1907	413,954 tons
1888	1,861 tons	1908	380,254 tons
1889	2,203 tons	1909	457,562 tons
1890	3,459 tons		

[a] In long tons of 2,240 pounds.

PRODUCTION OF SUGAR BEETS AND OF BEET SUGAR IN THE UNITED STATES, 1901-1909.

The following statements are taken from Report No. 92, Progress of the Beet-Sugar Industry in the United States in 1909:

The acreage planted to sugar beets in the United States in 1908, together with the percentage abandoned owing to unfavorable weather conditions, mistakes of growers, or other causes, is shown in the following table:

Acres planted to beets in 1909.

State.	Planted.	Abandoned.	State.	Planted.	Abandoned.
	Acres.	*Per cent.*		*Acres.*	*Per cent.*
California	93,267	11.0	Wisconsin	15,000	6.7
Colorado	136,882	11.0	Ten other States	50,970	16.4
Idaho	16,086	4.1			
Michigan	120,175	6.6	The United States	464,675	9.6
Utah	32,295	3.1			

Comparison with the acreage harvested shows that over 44,400 acres, or 9.6 per cent of the acreage planted, were abandoned. Comparison with the figures for the preceding year shows that the acreage planted exceeds that for 1908 by 43,300 acres, while the acreage harvested is about 55,349 more, the acreage abandoned in 1908 being 13.4 per cent. The large increase of harvested acreage occurred mainly in the States of California and Michigan, each increasing 32 per cent, while Colorado and Utah remained about the same and Idaho showed a decrease of 26 per cent.

General factory and farm results.

BY STATES, FOR 1909.

State and year.	Factories in operation.	Area harvested.	Average yield of beets per acre.	Beets worked.	Sugar manufactured.	Average extraction of sugar based on weight of beets.	Average sugar in beets.	Average purity coefficient of beets.[a]	Average length of campaign.
		Acres.	*Tons.*[b]	*Tons.*[b]	*Pounds.*	*Per cent.*	*P. cent.*	*P. cent.*	*Days.*
California	10	83,000	10.63	882,084	254,544,000	14.43	17.61	83.62	102
Colorado	16	121,698	10.33	1,256,771	298,810,000	11.89	14.24	80.51	85
Idaho	3	15,434	10.60	163,557	39,988,000	12.22	15.98	86.17	83
Michigan	16	112,232	7.31	819,923	212,106,000	12.93	17.00	86.21	74
Utah	5	31,293	14.54	455,064	97,768,000	10.74	15.04	84.22	128
Wisconsin	4	14,000	10.21	143,000	34,340,000	12.01	15.88	85.17	63
States having but a single factory each:[c] Arizona, Illinois, Iowa, Kansas, Minnesota, Montana, Nebraska, New York, Ohio, Oregon, Washington	11	42,605	8.47	360,983	87,382,000	12.10	15.09	83.21	61
Totals and averages[d]	65	420,262	9.71	4,081,382	1,024,938,000	12.56	16.10	84.11	83

TOTALS AND AVERAGES, BY YEARS, 1901–1908.[d]

1908	62	364,913	9.36	3,414,891	851,768,000	12.47	15.74	83.5	74
1907	63	370,984	10.16	3,767,871	927,256,430	12.30	15.8	83.6	89
1906	63	376,074	11.26	4,236,112	967,224,000	11.42	14.9	82.2	105
1905	52	307,364	8.67	2,665,913	625,841,228	11.74	15.3	83.0	77
1904	48	197,784	10.47	2,071,539	484,226,430	11.69	15.3	83.1	78
1903	49	242,576	8.56	2,076,494	481,209,087	11.59	[e] 15.1	(*f*)	75
1902	41	[g] 216,400	8.76	1,895,812	436,811,685	11.52	[e] 14.6	[e] 83.3	94
1901	36	175,083	9.63	1,685,689	369,211,733	10.95	14.8	82.2	88
Averages, 1901–1908		281,397	9.70	2,726,790	642,943,574	11.76	15.2	83.1	85

[a] By purity coefficient is meant the percentage of sugar in the total solids of the substance tested, whether it be beets, juice, or sugar. In this table it represents the average percentage of sugar in the total solids of the juice of the beets as determined by tests made at the factories.

[b] Tons of 2,000 pounds each.

[c] Grouped together to avoid giving publicity to data relating to individual factories.

[d] The average yield of beets per acre is found by dividing the total beets worked by the total acreage harvested; the average extraction of sugar by dividing the total sugar produced by the total beets worked; the average content of sugar, coefficients of purity, and length of campaign by adding the figures reported by the different factories and dividing by the number of reporting factories.

[e] These averages are not based on data for all the factories, as some of them failed to report results of tests, but it is believed that they fairly represent the character of the total beet crops.

[f] No data reported.

[g] Based on reports from 27 factories and careful estimates for 14 others.

CONSUMPTION OF SUGAR IN THE UNITED STATES.

The following table shows the quantities of imported sugar (both cane and beet) consumed in this country during the past three years, the quantity of domestic cane, beet, and maple sugars, and the quantities of sugar made in this country from imported molasses. Of the total quantity consumed in 1909, nearly 74 per cent was imported from either foreign countries or the insular possessions of the United States, while less than 13½ per cent was domestic beet sugar. The total annual consumption has reached 3¼ million tons of 2,240 pounds.

Consumption of sugar in the United States, 1907–1909.

[According to Willett & Gray, January 6, 1910.]

Kind and origin.	1907.	1908.	1909.
	Tons.[a]	*Tons.*[a]	*Tons.*[a]
Cane and beet sugar from foreign countries and insular possessions	2,337,352	2,284,791	2,393,564
Cane sugar, Louisiana and Texas	264,968	390,888	409,960
Beet sugar, United States	375,410	493,200	434,000
Maple sugar	10,000	11,000	11,000
Molasses sugar, made in United States from foreign molasses	6,249	5,910	9,136
Total domestic sugar	656,627	900,998	864,096
Total consumption of all sugars	2,993,979	3,185,789	3,257,660

[a] Tons of 2,240 pounds.

The total annual consumption of sugar in the United States, the percentage of increase or decrease year after year, and the per capita consumption for the years 1884–1909 are shown in the table which follows. The total consumption has increased over 160 per cent, while the per capita consumption has increased more than 60 per cent since 1884.

Consumption of sugar in the United States for twenty-four years, 1884–1909.

[According to Willett & Gray, January 6, 1910.]

Year.	Total amount sugar consumed.	Increase (+) or decrease (−).[a]	Consumption per capita.	Year.	Total amount sugar consumed.	Increase (+) or decrease (−).[a]	Consumption per capita.
	Tons.[b]	*Per cent.*	*Pounds.*		*Tons.*[b]	*Per cent.*	*Pounds.*
1884	1,252,366	+ 7.01	51.00	1897	2,070,978	+6.75	63.50
1885	1,254,116	+ 0.14	49.95	1898	2,002,902	−3.29	60.30
1886	1,355,809	+ 8.11	52.55	1899	2,078,068	+3.75	61.00
1887	1,392,909	+ 2.74	53.11	1900	2,219,847	+6.83	66.60
1888	1,457,264	+ 4.62	54.23	1901	2,372,316	+6.87	69.70
1889	1,439,701	− 1.21	52.64	1902	2,566,108	+8.17	72.80
1890	1,522,731	+ 5.77	54.56	1903	2,549,642	−0.64	70.90
1891	1,872,400	+22.96	67.46	1904	2,767,162	+8.53	75.30
1892	1,853,370	− 1.02	63.76	1905	2,632,216	−4.88	70.50
1893	1,905,862	+ 2.83	63.83	1906	2,864,013	+8.81	76.10
1894	2,012,714	+ 5.55	66.64	1907	2,993,979	+4.54	77.54
1895	1,949,744	− 3.13	64.23	1908	3,185,789	+6.40	81.17
1896	1,940,085	− 0.49	60.90	1909	3,257,660	+2.25	81.80

[a] As compared with the preceding year. [b] Tons of 2,240 pounds.

Although in recent years the beet-sugar industry has made great strides in the United States, and there has been some growth of the cane-sugar industry, the increase in production has not by any means kept pace with the increase in consumption. In fact, much more foreign sugar is consumed now than was the case ten years ago. In 1899 our total consumption of sugar was 2,078,068 long tons; in 1909 it was 3,257,660 tons, an increase in ten years of 1,179,592 tons. During the same period the increase in domestic production has been only about 385,000 tons.

SUGAR IMPORTED FOR CONSUMPTION.

The next table shows the character of the sugar imported for consumption, and its origin. In 1909 over 91 per cent of the sugar imported came from Hawaii, Porto Rico, the Philippines, and Cuba under tariff concessions, while only about 9 per cent came from other countries paying full duty. The imports from both Porto Rico and Cuba are steadily increasing, Cuba alone furnishing nearly 60 per cent of the foreign sugar consumed in the United States in 1909, and about 44 per cent of the total sugar consumed. It will be noticed that nearly all the imported sugar consumed in the United States is made from cane; in 1907 less than 1 per cent was from beets, in 1908 less than 7 per cent, and in 1909 less than 0.03 per cent. In fact, if the beet sugar made in the United States be included, it appears that only about 13 per cent of the sugar consumed in this country in 1909 was made from beets.

Consumption of imported sugar, 1907–1909.

[According to Willett & Gray, January 6, 1910.]

Kind and origin.	1907.	1908.	1909.
Imports on which tariff concession is allowed:	*Tons.* [a]	*Tons.* [a]	*Tons.* [a]
From Hawaii, cane sugar	418,102	453,250	483,671
From Porto Rico, cane sugar	212,853	185,085	235,117
From Philippines, cane sugar	10,700	45,089	46,804
From Cuba, cane sugar	1,340,400	916,742	1,427,531
Total	1,982,055	1,600,166	2,193,123
Imports on which full duty is assessed:			
Foreign sugar—			
Raw cane	347,509	543,518	199,675
Raw beet	6,780	139,363	.....
Refined beet	949	1,687	643
Refined cane	59	57	123
Total	355,297	684,625	200,441

[a] Tons of 2,240 pounds.

THE WORLD'S SUGAR CROP.

The following table was prepared in the Bureau of Statistics, U. S. Department of Agriculture, and published in the Yearbook of the Department of Agriculture for 1909:

Sugar production of countries named, 1905–6 to 1909–10.

[European beet sugar, as estimated by Licht; United States beet sugar, from reports of Department of Agriculture on the Progress of the Beet-Sugar Industry in the United States; production of British India, except 1909–10, from official statistics; other data, from Willett & Gray. The estimates of Willett & Gray do not include the production of China and some other less important sugar-producing countries.]

Country.	1905–6.	1906–7.	1907–8.	1908–9.	1909–10.
CANE SUGAR.					
NORTH AMERICA.					
United States:					
Contiguous—	*Tons.*[a]	*Tons.*[a]	*Tons.*[a]	*Tons.*[a]	*Tons.*[a]
Louisiana	336,752	230,000	340,000	355,000	325,000
Texas	12,000	13,000	12,000	15,000	10,000
Noncontiguous—					
Hawaii	383,225	392,871	465,288	477,817	490,000
Porto Rico	213,000	210,000	200,000	245,000	280,000
Total United States (except Philippine Islands)	944,977	845,871	1,017,288	1,092,817	1,105,000
Central America:					
Costa Rica	1,377	2,365	2,415	2,500	2,500
Guatemala	6,795	7,469	7,178	7,500	7,500
Nicaragua	4,400	3,905	4,175	4,500	4,500
Salvador	5,944	6,008	5,490	6,500	6,500
Mexico	107,529	119,496	123,285	125,000	130,000
West Indies:					
British—					
Antigua and St. Kitts	24,000	28,319	20,000	24,000	25,000
Barbados[b]	49,864	32,950	31,852	13,128	40,000
Jamaica[b]	12,523	13,971	10,718	11,453	12,000
Trinidad[b]	56,455	45,631	41,626	44,512	45,000
Cuba	1,178,749	1,427,673	961,958	1,513,582	1,700,000
Danish—St. Croix	13,000	13,000	13,000	14,000	15,000
French—					
Guadeloupe	36,000	38,960	37,500	25,211	43,000
Martinique[b]	42,231	36,764	35,943	37,757	40,000
Haiti and Santo Domingo	55,090	60,000	60,000	80,000	90,000
Other	13,000	5,662	5,000	6,000	6,000
Total	2,551,934	2,688,044	2,377,428	3,008,460	3,272,000
SOUTH AMERICA.					
Argentina	137,308	116,287	109,445	162,479	125,000
Brazil	275,000	215,000	180,000	248,000	276,000
British Guiana[b]	121,693	120,334	99,737	117,176	115,000
Dutch Guiana	13,000	13,000	13,000	14,000	15,000
Peru	150,000	161,156	135,336	150,000	150,000
Venezuela	3,000	3,000	3,000	3,000	3,000
Total	700,001	628,777	540,518	694,655	684,000
EUROPE.					
Spain	15,722	16,400	11,000	20,000	16,000
ASIA.					
British India[c]	1,725,500	2,205,300	2,046,900	1,841,800	1,800,000
Formosa	64,190	81,448	68,450	120,000	130,000
Java	990,994	1,011,546	1,156,477	1,241,885	1,185,000
Philippine Islands[d]	145,525	145,500	150,000	150,000	145,000
Total	2,926,209	3,443,794	3,421,827	3,353,685	3,260,000
AFRICA.					
Egypt	65,000	42,195	55,648	55,000	55,000
Mauritius	188,364	220,000	170,000	195,000	230,000
Natal	26,603	27,130	24,222	31,992	65,000
Réunion	38,000	37,500	35,000	37,000	45,000
Total	317,967	326,825	284,870	318,992	395,000

[a] Tons of 2,240 pounds, except beet sugar in Europe, which is shown in metric tons of 2,204.622 pounds.
[b] Exports.
[c] Official estimates for such parts of British India as return statistics of production.
[d] After 1907–8, exports.

Sugar production of countries named, 1905–6 to 1909–10—Continued.

Country.	1905–6.	1906–7.	1907–8.	1908–9.	1909–10.
OCEANIA.					
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Australia:					
Queensland	170,000	182,000	188,307	151,098	133,578
New South Wales	20,000	24,000	23,418	15,000	14,750
Fiji[a]	40,000	43,000	69,000	65,000	69,000
Total	230,000	249,000	280,725	231,098	217,328
Grand total, cane sugar	6,741,833	7,352,840	6,916,368	7,626,890	7,844,328
BEET SUGAR.					
NORTH AMERICA.					
United States	279,393	431,796	413,954	380,254	457,562
Canada	11,419	11,367	7,943	6,964	8,802
Total	290,812	443,163	421,897	387,218	466,364
EUROPE.					
Austria-Hungary	1,509,789	1,343,940	1,424,657	1,398,000	1,260,000
Belgium	328,770	282,804	232,352	258,000	250,000
France	1,089,684	756,094	727,712	802,000	825,000
Germany	2,418,156	2,239,179	2,129,597	2,080,000	2,040,000
Netherlands	207,189	181,417	175,184	214,000	200,000
Russia	968,500	1,440,130	1,410,000	1,265,000	1,150,000
Other countries	410,255	467,244	462,772	500,000	460,000
Total	6,932,343	6,710,808	6,562,274	6,517,000	6,185,000
Grand total, beet sugar	7,223,155	7,153,971	6,984,171	6,904,218	6,651,364
Grand total, cane and beet sugar	13,964,988	14,506,811	13,900,539	14,531,108	14,495,692

[a] Exports.

THE BEET-SUGAR INDUSTRY OF EUROPE.

The following table shows the enormous proportions to which the beet-sugar industry has developed throughout central Europe and especially in Germany, Austria, and Russia. The figures for 1909 for the United States have been included for sake of comparison.

Number of factories, yield of beets per acre, and yield of sugar in the principal beet-sugar countries of Europe in 1908–9.

[F. O. Licht, Report, March 18, 1910.]

Data.	Germany.	Austria.	France.	Russia.	Belgium.	Holland.	Sweden.	Denmark.	United States.
Acres in beets	1,071,000	816,000	528,000	1,371,000	141,200	119,800	77,000	37,500	420,262
Average tons to acre	10.99	9.75	10.91	6.14	12.00	11.29	11.10	11.98	9.71
Number of factories	358	204	251	277	81	27	21	7	65
Yield of sugar:									
Per 100 beets (per cent)	17.63	17.52	13.35	14.97	15.14	15.67	15.13	14.98	12.56
Per acre (pounds)	4,260	3,820	3,240	2,021	4,001	3,895	3,633	3,950	2,429

CONSUMPTION OF SUGAR IN EUROPE.

Mr. F. O. Licht, a high authority on European beet-sugar statistics, in a report dated December 9, 1909, estimates the per capita consumption of sugar in European countries as follows:

European per capita consumption of sugar for the year ending August 31, 1909.

	Pounds.		Pounds.
Germany	43.54	Spain	11.86
Austria	24.77	Portugal and Madeira	13.67
France	37.28	England	90.68
Russia	20.10	Bulgaria	7.98
Holland	43.67	Greece	8.36
Belgium	33.42	Servia	7.69
Denmark	78.35	Turkey	12.50
Sweden	54.03	Switzerland	66.65
Norway	39.29		
Italy	8.64	North America	82.14
Roumania	9.15		

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